2. Required ACM Capabilities

This Chapter specifies required capabilities that an ACM will be tested for and specifies how the reference computer simulation program will be used for required modeling capabilities. All of the required capabilities are described in terms of the capabilities and algorithms of the Commission's reference program. An ACM shall account for the energy performance effects of all of the features described in this chapter.

The modeling procedures and assumptions described in this chapter apply to both the *standard design* and *proposed design*. The requirements for the *standard design* include those that ACMs shall apply to new features, altered existing features, unchanged existing features or all of the above. In order for an ACM to become approved, it shall, at a minimum, accept all of the required inputs and meet the test criteria when compared against the reference computer program using procedures and assumptions as required in the sections describing the capabilities.

2.1 Compliance

2.1.1 Type of Project Submittal

ACMs shall require the user to identify the type of project for which compliance is being demonstrated. The ACMs shall require the user to choose one of the following options:

- New Building
- Addition Alone (modeled as new building but labeled on output) (when ACM is approved for this optional capability)
- Addition Plus Alteration of Existing Building (when ACM is approved for this optional capability)
- Alteration of Existing Building (when ACM is approved for this optional capability)

These compliance options are required even though compliance for existing buildings is an optional capability. Optional capabilities are described in the following chapter of this manual. An ACM shall not produce compliance reports or operate in a compliance mode when users specify features that require optional modeling capabilities for which the ACM is not approved.

2.1.2 New Building or Addition Alone

ACMs are required to be able to perform compliance on new buildings and additions as if they were new (or newly conditioned), stand-alone, buildings. ACMs may do this by treating an addition alone as a new building, but an addition modeled in this way shall be reported on all output forms as a **Stand Alone Addition.**

2.1.3 Scope of Compliance Calculations

For each building or separately permitted space, ACMs shall also require the user to identify the scope of the compliance submittal from the following list:

- Envelope only
- Mechanical only
- Envelope and Lighting
- Envelope and Mechanical
- Lighting and Mechanical

- Envelope, Lighting and Mechanical

Each of these situations requires specific assumptions, input procedures and reporting requirements. Modeling assumptions are documented in Chapters 2 and 3. Reporting requirements are documented in Chapter 4. *ACMs shall only produce reports specific to the scope of the submittal determined for the run.* Hence an Envelope Only scope run is only allowed to produce ENV forms and PERF forms that are designated *Envelope Only*.

The information about installed service water heating system(s) is included in the mechanical compliance submittal forms. ACMs shall calculate the energy use for both the proposed system(s) and the reference system(s) [TDV energy budget] and provide the results on the PERF forms. The energy budget is calculated in accordance with Section 2.6 (Service Water Heating--Required capabilities) of this manual. If the energy used by the proposed water heating system(s) is less than the energy budget, the credit may be traded off for other building features. Alternatively, for high-rise residential buildings, users may show service water heating compliance by meeting the prescriptive requirements of Section 151(f)(8) of the Standards. When the compliance for the service water heating is shown prescriptively, tradeoff between the service water heating and other building components is not allowed.

When a building has a mixed scope of compliance, such as a speculative building where all the envelope is being permitted but the core includes lighting as well as portions of the envelope, **two** (or more) compliance runs shall be performed and forms from different runs shall be submitted for the appropriate spaces. The scope of submittal for the building core compliance run will be **Envelope & Lighting** and the scope of submittal for the compliance run for the remainder of the building will be **Envelope Only**.

The following modeling rules apply for when the scope of the compliance calculations do not include one of the following: the building envelope, the lighting system or the mechanical system.

Cases	*Modeling Rules for Proposed Design*	*Modeling Rules for Standard Design (All):*
No Envelope Compliance Mechanical Only Lighting and Mechanical	The envelope shall be modeled according to the as-built drawings and specifications of the building or as it occurs in the previously-approved compliance documentation of the building. All envelope features and inputs required for ACMs by this manual shall be entered. Note: A partial permit application involving no envelope compliance creates an exceptional condition. This requires either a copy of the previous envelope compliance approval or an equivalent demonstration by the applicant (to the satisfaction of the local enforcement agency) that the building is conditioned and an occupancy permit has previously been issued by the local enforcement agency. The exceptional condition list shall indicate the presence of an existing or previously-approved envelope documentation and a form shall be produced to document the existing envelope. No envelope (ENV) compliance forms may be output as part of the compliance output when the user selects this option.	The envelope shall be identical to the proposed design.

No Mechanical Compliance Envelope Only Envelope and Lighting	ACMs shall model default heating and cooling systems according to the rules in Section 2.5.3.9 (Modeling Default Heating and Cooling Systems). ACMs may not allow the entry of an HVAC system and shall automatically model the default system. Economizer controls will be modeled as indicated in the Standard Design Assumptions for Air Economizers based on system total (sensible + latent) cooling capacity.	The mechanical systems shall be identical to the proposed design.
No Lighting Compliance Envelope Only Mechanical Only Envelope and Mechanical	Previously-approved lighting plans with approved lighting compliance forms may be entered as Tailored Lighting at the approved lighting power levels shown in the construction and previously-approved compliance documents and installed as approved. The exceptional conditions list on the PERF-1 form shall indicate that previously-approved lighting plans and compliance forms shall be resubmitted with the application. In the absence of approved lighting plans and lighting compliance forms, the ACM shall model the lighting system according to Section 2.4.2.1 (Lighting) using the rules for Lighting compliance not performed.	With previously approved lighting plans, the lighting levels for each space shall be equal to the approved design. No lighting (LTG) compliance forms may be output with the compliance output. The local enforcement agency should verify that the lighting has already been approved and installed or, if recently designed and approved, should verify the independent lighting approval. In the absence of approved lighting plans and lighting compliance forms, the ACM shall model the lighting system according to Section 2.4.2.1 (Lighting) using the rules for Lighting compliance not performed.

2.1.4 Climate Zones

The program shall account for variations in energy use due to the effects of the sixteen (16) California climate zones. Climate information for compliance simulations shall use one of sixteen (16) data sets described in ACM Joint Appendix II. However, the data may be adjusted to local conditions by methods described in ACM Joint Appendix II. The same weather data shall be used for the standard and proposed designs. The ACM shall accept input for latitude, longitude and elevation for the local condition. The candidate ACM shall use a full 8760-hour year of data, since TDV multipliers are applied for each hour.

2.1.5 Reference Year

The reference year determines the day (Monday, Tuesday, etc.) for the first day in the weather file which in turn determines the weather days for which holidays and weekends occur. Nonresidential ACMs shall use the Reference Year as specified in Joint Appendix II.

2.1.6 Time Dependent Valuation

The candidate ACM shall calculate the hourly energy use for both the standard design and the proposed design by applying a TDV factor for each hour of the reference year. TDV factors have been established by the CEC for residential and nonresidential occupancies, for each of the sixteen climate zones, and for each fuel (electricity, natural gas, and propane). The procedures for Time Dependent Valuation of energy are documented in ACM Joint Appendix III.

2.1.7 Reference Method Comparison Tests

A specific set of reference method comparison tests are described in Chapter 5. These tests verify that the differences between the reference method's compliance margins and an ACM's compliance margins meet specific criteria. The criteria shall be met for every test. The criteria are designed to minimize the possibility that an approved ACM will “pass” a building when the reference method would not. The test criteria do not prevent an ACM from being conservative with regard to compliance but requires the ACM to produce results similar to those of the Commission’s reference program. In addition to meeting the test criteria, the ACM shall conform to all of the input and output requirements described in this manual.

An ACM may use the reference method procedures directly or the ACM may use other procedures that approximate the reference method results with sufficient accuracy to meet the criteria described in Chapter 5. In particular, when this manual uses the term “ACMs shall model” it means that ACMs shall be able ***to quantitatively approximate*** the changes in energy use due to particular envelope, lighting, or HVAC features of a building in such a way that satisfies the test criteria in Chapter 5 for each and every test. ACM estimates for lighting and receptacle energy use shall be within a few percent of the reference method results, while a larger tolerance is acceptable for HVAC and building envelope measures.

2.2 Compliance Documentation

Compliance documentation includes the forms, reports and other information that is submitted to the building department with an application for a building permit. The purpose of the compliance documentation is to enable the plans examiner to verify that the building design complies with the Standards and to enable the field inspector to readily identify building features that are required for compliance.

ACMs must automatically produce the CEC standard reports which are an essential part of the compliance documentation. The standard reports are highly restricted in quantity and format. All non-default inputs shall be reported on the appropriate report. Exceptional user entries outside of "normal" range shall be printed and shall be clearly flagged in the compliance documentation for the attention of the plan checker and field inspector. Exceptional user entries include process loads, tailored ventilation, and tailored lighting and modifications to certain default values. When the user enters such exceptional input in compliance calculations, the ACM shall automatically print the forms containing such user inputs. Exceptional conditions shall be indicated on the PERF-1 form. The exceptional conditions section shall be prominent on the compliance documentation and shall be included even if no exceptional conditions are reported.

The ACM shall automatically determine the forms to be printed and the total number of pages (T) required to print those forms and shall print exactly that number of pages and all ACM-determined forms. This determination shall be made based on the user's description of the scope of compliance, the building characteristics, and the user's selection of a compliance run. ACMs may not allow the user to select specific forms to be printed in a compliance run (as distinguished from a diagnostic run where specific reports may be requested). Each page (N) of the required output shall indicate Page N of T in the page header, the unique compliance run code, and the time of the compliance run. The PERF-1 shall list or indicate all of the forms required for a valid submittal, including those required to be done by hand.

An ACM shall produce the compliance documentation (in a format approved by the Commission) only when a modeled building design complies with the Standards. Reports not directly related to compliance and not required to be reported in this manual shall not be included in the compliance documentation. Too much or too little information obstructs enforcement. Secondary or irrelevant information may confuse the building official or wastes his/her time. On the other hand, a lack of relevant information may lead to enforcement errors or encourage cheating. To be approved for compliance use, an ACM cannot allow the user to directly select the compliance forms to be printed. Each ACM shall determine the compliance output based on the user's input description of the building and the type of compliance run for the building. ACMs may produce additional reports which are not part of the compliance documentation, but these reports should be formatted to make it clear to the plans examiner and the field inspector that the reports are not part of the compliance documentation.

The standard reports are intended to be as similar as possible to the compliance forms used in the prescriptive compliance approach so that those who are familiar with the prescriptive forms will more easily be able to find information on performance approach reports. To allow the optional capabilities of Partial Compliance, Alterations, or automatic modeling of Additions Modeled with the Existing Building, there are distinct additional forms describing existing building components and systems that shall be printed separately than the forms describing the altered or new building components and systems and shall have **all** text in lowercase type.

The first pages (signature pages) of the prescriptive ENV-1, LTG-1, and MECH-1 certificates of compliance are consolidated on the first page of the PERF-1 form. The PERF-1 is the Certificate of Compliance for the performance approach and all three parts of the PERF-1 form (at least three pages) shall be included as part of the plans. Typically the pages of these forms are adhered to a plan sheet and submitted with the plans. These forms are considered to be an integral part of the plans and are to be recorded in exactly the same manner as a set of plans and retained for the same period of time as official records of the plans.

An ACM shall not print compliance documentation when a proposed building design does not comply with the Standards, i.e. when a proposed building design modeled by an approved ACM in accordance with the reference procedure has an estimated TDV energy that exceeds the TDV energy budget, compliance forms shall not be printed, displayed on screen, or written on disk. An ACM may produce diagnostic reports for buildings that do not comply. These diagnostic reports shall be formatted in a manner significantly different from the compliance documentation, and may include information to help the energy analyst identify measures to bring the building into compliance, including the TDV energy use components of the proposed design and the standard design. Non complying reports shall not report run codes, simulation times, or total page counts, approved form headers, header information or include any formatting features used for compliance documentation. Producing noncompliance reports that resemble compliance documentation is sufficient grounds for rejection of the ACM.

ACMs shall interlock program input and compliance output so that the two are always consistent. Any alterations in the user input shall result in a new run time, run code and completely new set of compliance documentation for the type of compliance selected.

User inputs shall appear on the ACM compliance documentation but the reporting of prescribed input assumptions is usually unnecessary since ACMs are required to automatically use these inputs. Compliance documentation shall only include the prescribed inputs or assumptions that are required by the building official to verify compliance. When inputs with standard defaults are modified by the user, the modified value shall be distinctly identified (flagged) in the compliance documentation to alert the local enforcement agency of an exceptional condition for compliance. This enables the code official to verify that the alternate value is acceptable for compliance, is consistent with the plans and specifications, and is verifiable in the field.

To accommodate the optional capabilities of partial compliance, alterations, and additions, ACMs shall report all new or altered user-entered building components and descriptive information completely in **UPPERCASE** type. ACMs with the capabilities for partial compliance, automatic modeling of additions with the existing building or modeling alterations in an existing building shall report all information on existing, previously-approved building components that are not altered in **lowercase** type. For partial compliance the ACM shall produce the special EXISTING-ENV forms for the existing envelope. Partial compliance applicants with building envelopes approved within the previous two years shall supply envelope compliance information along with the EXISTING-ENV forms. This is to insure that the local enforcement agency can verify that the existing envelope complies and to distinguish these modeled components (same for both standard design and proposed design) from those that are new or have been altered.

The required reports shown in this section should be formatted to fit a 8 ½ x 11 in. page.

2.2.1 Certificate of Compliance Form(s)

(PERF-1, ENV-1, EXISTING-ENV, LTG-1, EXISTING-LTG, MECH-1, and EXISTING-MECH)

The first standard report that shall be produced by all ACMs is the Certificate of Compliance which is divided into four sections: the Performance Summary (PERF-1 forms), Envelope (ENV-1 form), lighting (LTG-1 form) and mechanical (MECH-1 forms). The Certificate of Compliance is required by Title 10, Section 103(a) 2.A, B and C of the California Code of Regulations. For the performance approach all signature blocks for the Certificate of Compliance are combined onto the first page of the PERF-1 compliance output form. Normally all of these signature blocks shall be signed by the responsible designers. However, when an ACM is approved for optional partial compliance features and the partial compliance option is being used, only one or two of the signature blocks need be filled in. However, when this occurs the signatures shall be consistent with the type of partial compliance indicated on the Certificate of Compliance - PERF-1 forms and information reported on other output reports. The following are items to be included on the PERF-1 report.

- Date
- Project Name
- Project Address
- Principal Designer Envelope
- Documentation Author
- Building Permit #
- Date of Plans
- Building Conditioned Floor Area
- Climate Zone Building Type
- Phase of Construction
- Statement of Compliance (signature of documentation author)
- Envelope compliance (signature of licensed engineer/architect/contractor, date, license number)
- Lighting compliance (signature of licensed engineer/architect/contractor, date, license number)
- Mechanical compliance (signature of licensed engineer/architect/contractor, date, license number)
- Annual TDV Energy Use Summary
- Building Complies – General Information
- Zone Information
- Exceptional Conditions Compliance Checklist

The PERF-1 shall list all optional capabilities utilized by the user and shall identify the zone(s), system(s) and/or plant(s) to which the optional capabilities apply. The PERF-1 shall also itemize the use of any of the following exceptional building compliance features on the exceptional conditions checklist, identifying the zone(s), systems(s) and or plant(s) to which the feature(s) apply.

The following are examples of building features that should be listed in the exceptional features section.

- Absorptance < 0.40
- Exterior surface emittance different from DOE2.1E defaults
- Any user-defined materials, layers, constructions, assemblies
- Window-wall-ratio > 0.40
- Skylight-roof-ratio > 0.05
- Solar heat gain coefficient (vertical or horizontal) < 0.40
- Fenestration u-factor (vertical or horizontal) < 0.50
- Use of “Alternate Default Fenestration Thermal Properties”
- Use of “Field-Fabricated Fenestration”
- Use of "Industrial/Commercial Work - Precision" occupancy
- Process fan power
- Process loads
- Tailored lighting input
- Lighting control credits
- Electric resistance heating or reheating
- Hydronic (water source heat pumps)
- Economizer installed on equipment below 75,000 Btu/h and 2500 cfm
- Tailored ventilation
- Demand control ventilation
- Variable speed drive fans
- Other high efficiency fan drive motors
- Verified sealed ducts in ceiling/roof spaces
- Any optional capabilities used

One consequence of **partial compliance** is that fewer compliance reports are required. The reports, the total number of pages, the run code, and time printed on each of the forms shall be consistent with the fewer number of pages allowed for partial compliance.

The PERF-1 form shall also provide information on the service water heating system, including the system type, the efficiency of the water heating system or its components, pipe insulation specifications, and the fuel source used for service hot water.

When partial compliance is used or an addition is modeled with an existing building and its existing building components, these components shall be flagged on the exceptional conditions checklist on the PERF-1 forms and the relevant EXISTING forms shall be produced.

2.2.2 Supporting Compliance Forms

The second type of standard reports that shall be produced by all ACMs are the supporting compliance forms. These are summarized below.

ENV-1	Envelope Compliance Summary – Performance	Opaque Surfaces Fenestration Surfaces – Site Assembled Glazing Exterior Shading
MECH-1	Certificate of Compliance Summary – Performance	System Features
MECH-1	Mechanical Compliance Summary – Performance	Duct Insulation Pipe Insulation
MECH-2	Mechanical Equipment Summary – Performance	Chiller and Tower Summary DHW/Boiler Summary Central System Ratings Central Fan Summary VAV Summary Exhaust Fan Summary
MECH-3	Mechanical Compliance Summary – Performance	Mechanical Ventilation
MECH-5	Mechanical Distribution Summary – Performance Use Only	Verified Duct Tightness by Installer HERS Rater Compliance Statement
LTG-1	Certificate of Compliance – Performance	Installed Lighting Schedule Mandatory Automatic Controls Controls for Credit
LTG-1	Portable Lighting Worksheet – Performance	Portable lighting not shown on plans for office areas > 250 square feet Portable lighting shown on plans for office areas > 250 square feet Plans show portable lighting is not required for office areas > 250 square feet Building Summary – Portable Lighting

If the ACM produces additional reports, the pages of these reports shall be tabulated and counted along with the performance forms for total page counts and verification on the PERF-1 form. Applicable reports (forms) shall not be included with compliance calculations unless the report is relevant.

2.3 Building Shell

All ACMs shall accept inputs for each different opaque surface (wall, roof/ceiling, or floor) that separates the conditioned space from the unconditioned or semi-conditioned space or the ground, including each demising wall (which consequently includes each party wall). These inputs include construction framing type, orientation and tilt, location and area for each exterior surface. An ACM shall also allow the user choose construction assemblies from ACM Joint Appendix IV. The choice determines the heat transfer and heat capacity characteristics. The choice also determines the standard design construction. Standard design Roof/Ceiling assemblies shall meet requirements of Standards Section 118 (e).

U-factors of exterior surfaces shall be obtained from ACM Joint Appendix IV.

Standard design requirements are labeled as applicable to one of the following options:

- Existing unchanged
- Altered existing
- New
- All

The default condition for these four specified conditions is "All." An ACM without the optional capability of analyzing additions or alterations shall classify and report all surfaces as "All."

All ACMs shall separately report information about demising walls, fenestration in demising walls, exterior walls, and fenestration in exterior walls. Demising walls and demising wall fenestration separate conditioned spaces from enclosed unconditioned spaces. Party walls are always considered to be demising walls when they separate spaces controlled or occupied by different tenants. For the purpose of compliance, the adjacent enclosed spaces not controlled by the tenant of the given space or by a single manager of the building are unconditioned. This assumption means that party walls are treated as demising walls and adjacent tenant spaces are modeled as enclosed unconditioned spaces. To avoid modeling adjacent spaces that are not part of the permit, for purposes of Standards compliance, an ACM shall assume that the demising wall is adiabatic and no heat transfer occurs through it.

2.3.1 Spaces

2.3.1.1 Directly Conditioned Space

Directly conditioned space is space in a building that is directly heated and/or cooled through the delivery of conditioned air or by radiation from heating elements or interior surfaces.

2.3.1.2 Return Air Plenums

Return air plenums are considered conditioned spaces and shall be modeled as part of the adjacent conditioned space.

2.3.1.3 Indirectly Conditioned Spaces

ACMs shall allow users to explicitly model all indirectly conditioned spaces. The internal loads (people, lights, equipment, etc.) and schedules for conditioned spaces shall also be used for indirectly conditioned spaces. When indirectly conditioned spaces are explicitly modeled, ACMs shall require the user to identify each zone as either directly or indirectly conditioned.

At the user's choice, ACMs may model indirectly conditioned spaces as part of the directly conditioned space provided that the total volume and area of indirectly conditioned spaces included are each less than 15% of the total volume and less than 15% of the total conditioned floor area of the total indirectly and directly conditioned volume and floor area. (Refer to Chapter 4 for requirements applying to indirectly conditioned spaces included as directly conditioned spaces.) For the purposes of this manual, indirectly conditioned spaces can either be occupied or unoccupied. Descriptions of each of these space types are provided in Chapter 4. The requirements for each of these three cases are documented below.

Indirectly Conditioned Spaces Included in Directly Conditioned Space

Description	The requirements for modeling indirectly conditioned spaces when they are included in directly conditioned space are as described below.

DOE-2 Command	SPACE
DOE-2 Keyword(s)	AREA VOLUME MULTIPLIER
Input Type	Required
Tradeoffs	Neutral
Modeling Rules for Proposed Design:	Any indirectly conditioned space modeled as part of directly conditioned space shall be input as it occurs in the construction documents, including envelope, occupancy characteristics and lighting levels. Additionally, ACMs shall assume mechanical heating and cooling is provided to the space, using the same system as the actual directly conditioned space.
Modeling Rules for Standard Design (All):	ACMs shall use the same configuration and occupancy characteristics for indirectly conditioned spaces modeled as directly conditioned space as the proposed design. Standard design assumptions for envelope performance, occupancy characteristics, lighting levels, and HVAC system assumptions shall be determined as if the space were directly conditioned.

Indirectly Conditioned Spaces that can be Occupied and Explicitly Modeled

Description:	The requirements for modeling indirectly conditioned spaces that can be occupied and explicitly modeled are as described below.
DOE-2 Command	SPACE
DOE-2 Keyword(s)	AREA VOLUME MULTIPLIER
Input Type	Required
Tradeoffs	Neutral
Modeling Rules for Proposed Design:	For the proposed design ACMs shall receive input for indirectly conditioned spaces for area, configuration, and envelope as each space occurs in the construction documents. All internal loads, receptacle, occupant, process loads shall be determined identically to directly conditioned space. The reference method will treat the space as a conditioned zone [ZONE-TYPE = CONDITIONED] with heating and cooling off [HEATING-SCHEDULE & COOLING-SCHEDULE set to off] and fans on so that mechanical ventilation will be modeled according to Table N2-2 or Table N2-3.
Modeling Rules for Standard Design (All):	ACMs shall use the same configuration and modeling assumptions for indirectly conditioned spaces that can be occupied as the proposed design. Standard design assumptions for envelope performance shall be determined as if the space were directly conditioned. The reference method will not model mechanical heating or cooling for these spaces, however mechanical ventilation (CFM/ft^2) will be modeled according to Table N2-2 or Table N2-2. Lighting levels shall be established identical to directly conditioned space standard design.

Indirectly Conditioned Spaces that cannot be Occupied and Explicitly Modeled

Description	The requirements for modeling indirectly conditioned spaces that cannot be occupied and explicitly modeled are as described below.
DOE-2 Command	SPACE

DOE-2 Keyword(s)	AREA VOLUME MULTIPLIER
Input Type	Prescribed
Tradeoffs	Neutral
Modeling Rules for Proposed Design:	For the proposed design, all ACMs shall receive input for indirectly conditioned spaces for area, configuration, and envelope as each space occurs in the construction documents. All internal loads, ventilation, receptacle, lighting, occupant and process loads shall be zero. No mechanical heating, cooling or ventilation shall be modeled for indirectly conditioned spaces that cannot be occupied. As in the standard design, for these spaces the reference method models lightweight mass by using a light furniture category of 30 pounds per square foot in DOE 2.1 to generate the lightweight standard weighting factors for these spaces. This lightweight mass is meant to approximate the materials found in conditioned spaces that cannot be occupied.
Modeling Rules for Standard Design (All):	ACMs shall use the same configuration and modeling assumptions for indirectly conditioned spaces that cannot be occupied as the proposed design. Standard design assumptions for envelope performance shall be determined as if the space were directly conditioned. For these spaces the reference method models lightweight mass by using a light furniture category of 30 pounds per square foot in DOE 2.1 to generate the lightweight standard weighting factors for these spaces. This lightweight mass is meant to approximate the materials found in indirectly conditioned spaces that cannot be occupied. The reference method will not model mechanical heating, cooling or ventilation for indirectly conditioned spaces that cannot be occupied.

2.3.1.4 Enclosed Unconditioned

Description:	ACMs shall require the user to explicitly model any enclosed unconditioned spaces such as stairways, warehouses, unoccupied adjacent tenant spaces, attached sunspaces, attics and crawl spaces if and only if they are part of the permitted space. ACMs shall require the user to identify the space as unconditioned and to enter all applicable envelope information, in a similar manner to a conditioned space. If the enclosed unconditioned space is not a part of the permitted space, ACMs may allow the user to either explicitly model the space or ignore it by modeling the partition separating the condition space from the enclosed unconditioned space as an adiabatic demising partition (see Section 2.3.2.5).
DOE-2 Command	SPACE
DOE-2 Keyword(s)	AREA VOLUME MULTIPLIER
Input Type	Required
Tradeoffs	Neutral
Modeling Rules for Proposed Design:	If enclosed unconditioned spaces are explicitly modeled, ACMs shall model the envelope characteristics of the unconditioned spaces as input by the user, according to the plans and specifications for the building. All internal gains and operational loads (occupants, water heating, receptacle, lighting

and process loads, ventilation) in unconditioned spaces shall be equal to zero. Infiltration shall be equal to 0.038 times the total wall area exposed to ambient outdoor air.

If enclosed unconditioned spaces are not modeled, the reference program shall model the partitions separating condition spaces from enclosed unconditioned spaces as adiabatic demising partitions.

Modeling Rules for Standard Design (All):	ACMs shall model unconditioned spaces exactly the same as the proposed design.

2.3.1.5 Interior Mass

Description:	The heat capacity of interior walls and furniture.
DOE-2 Command	SPACE
DOE-2 Keyword(s)	FURNITURE-TYPE FURN-WEIGHT FURN-FRACTION
Input Type	Prescribed
Tradeoffs	Neutral
Modeling Rules for Proposed Design:	ACMs shall model interior mass as specified below. The reference method determines lightweight mass exclusively as a function of floor area using DOE-2 furniture inputs as described below. The reference method assumes that lightweight mass is determined from the floor area of the modeled spaces. In the reference method, lightweight mass is modeled through the use of the DOE 2.1 furniture inputs. For directly conditioned spaces and indirectly conditioned spaces that can be occupied the internal mass category is deemed to be [FURNITURE-TYPE = HEAVY]; the average weight of the light mass (furniture and equipment) is assumed to be 80 pounds per square foot [FURN-WEIGHT = 80]; and 85% of the floor is covered by lightweight (furniture) mass [FURN-FRACTION = 0.85]. This furniture fraction determines the fraction of solar gains going to the furniture/light mass. Thus the reference method assigns 85% of the total solar heat gain normally falling on the floor to the furniture instead. For indirectly conditioned spaces that cannot be occupied the internal mass category is deemed to be [FURNITURE-TYPE = LIGHT]; the average weight of the light mass (furniture and equipment) is assumed to be 30 pounds per square foot [FURN-WEIGHT = 30]; and 85% of the floor is covered by lightweight (furniture) mass [FURN-FRACTION = 0.85].
Modeling Rules for Standard Design (All):	The standard design shall model the same lightweight mass as the proposed design.

2.3.2 Construction Assemblies

Construction assemblies for the proposed design shall be selected from ACM Joint Appendix IV. When a choice is made, all properties of the proposed design construction assembly are set. The materials and layers that make up the construction assemblies are documented in the notes section of each table in ACM Joint Appendix IV. The choice from ACM Joint Appendix IV also determines the construction of the standard design, according to the mappings in Table N2-1.

Table N2-1 is first organized by type of construction: wall, roof or floor. The second column is the tables from ACM Joint Appendix IV for each type of construction. The third column links the tables to a class of construction. The final columns show the standard design construction assembly for each climate and building type. ***Selections from ACM Joint Appendix IV are referenced by row and column, similar to a spreadsheet. Letters are used for columns and numbers for rows.***

For mass walls, the process of choosing from ACM Joint Appendix IV is a bit more complicated. The user first chooses the mass layer from either Table IV-12 or Table IV-13. After that, the user may select an insulating layer from Table IV-14 for the outside of the mass wall and/or the inside of the mass wall. Up to three choices may be selected from ACM Joint Appendix IV. The mass layer selected by the user determines if the wall is medium mass or heavy mass. If the selected mass layer has an HC greater than or equal to 15.0 Btu/ft²-ºF, then the standard design mass layer is IV12-A8. If the selected mass layer has an HC greater than or equal to 7.0 Btu/ft²-ºF, but less than 15.0 Btu/ft²-ºF, then the standard design mass layer is IV12-B8. Table N2-1 shows the insulating layer from Table IV-14 that is added to the inside of the standard design mass layer.

Example

A user chooses the IV11-E3 steel framed wall construction from Table IV-11 of ACM Joint Appendix IV for a nonresidential building located in climate zone 12. Anytime a proposed design construction assembly is selected from Table IV-11, the class of construction for the proposed design is metal framing. The standard design construction assembly is IV11-A3 from Table N2-1.

Table N2-1 – Standard Design Construction Assemblies From ACM Joint Appendix IV

Type	ACM Joint Appendix IV Table	Class	Climate Zone	Non-residential	High Rise Residential and Hotel/Motel Guestrooms	Relocatable Classrooms
			Standard Design Construction Assembly			
Walls	Table IV.11 – Metal Framed Walls	Metal framing	1, 16	IV11-A3	IV11-A5	IV11-A3
			3-5	IV11-A2	IV11-A2	
			6-9	IV11-A2	IV11-A2	
			2, 10-13	IV11-A3	IV11-A3	
			14, 15	IV11-B5	IV11-A3	
	Table IV.16 – Metal Building Walls	Metal building	1, 16	IV16-A4	IV16-A5	IV16-A5
			3-5	IV16-A3	IV16-A3	
			6-9	IV16-A3	IV16-A3	
			2, 10-13	IV16-A4	IV16-A4	
			14, 15	IV16-A4	IV16-A4	
	Table IV.12 – Hollow Unit Masonry Walls Table IV.13 – Solid Unit Masonry and Solid Concrete Walls Table IV.19 – Effective R-values for Interior or Exterior Insulation Layers	Med. mass (For CZ 1, 16, the mass layer from IV13 is combined with furring from IV 19.)	1, 16	IV13-B5 IV19-D9	IV13-B5 IV19-D9	IV13-B5 IV19-D9
			3-5	IV12-C10	IV12-C10	
			6-9	IV12-C10	IV12-C10	
			2, 10-13	IV12-C10	IV12-C10	
			14, 15	IV12-C10	IV12-C10	
	Table IV.12 – Properties of Hollow Unit Masonry Walls Table IV.13 – Properties of Solid Unit Masonry and Solid Concrete Walls Table IV.19 – Effective R-values for Interior or Exterior Insulation Layers	Heavy mass (For CZ 1, 16, the mass layer from IV12 is combined with furring from IV 19.)	1, 16	IV12-A9 IV19-A6	IV12-A9 IV19-A6	n.a.
			3-5	IV12-A9	IV12-A9	
			6-9	IV12-A10	IV12-A10	
			2, 10-13	IV12-A9	IV12-A9	
			14, 15	IV12-C9	IV12-C9	
	Table IV.9 – Wood Framed Walls Table IV.10 –Structurally Insulated Wall Panels (SIPS) Table IV.17 – Thermal Properties of Log Home Walls Table IV.18 – Thermal and Mass Properties of Straw Bale Walls	Wood framing and Other	1, 16	IV9-A3	IV9-A5	IV9-A3
			3-5	IV9-A2	IV9-A2	
			6-9	IV9-A2	IV9-A2	
			2, 10-13	IV9-A3	IV9-A3	
			14, 15	IV9-A3	IV9-A3	
Roofs	Table IV.1 – Wood Framed Attic Roofs Table IV.2 – Wood Framed Rafter Roofs Table IV.3 – Structurally Insulated Panels (SIPS) Roof/Ceilings Table IV.5 – Metal Framed Rafter Roofs Table IV.6 – Span Deck and Concrete Roofs Table IV.7 – U-factors for Metal Building Roofs Table IV.8 – Insulated Ceiling with Removable Panels	All	1, 16	IV2-A5	IV2-A9	IV2-A5
			3-5	IV2-A5	IV2-A5	
			6-9	IV2-A2	IV2-A5	
			2, 10-13	IV2-A5	IV2-A9	
			14, 15	IV2-A5	IV2-A9	
Floors	Table IV.25 – Concrete Raised Floors	Medium or heavy mass	1, 16	IV25-A5	IV25-A5	IV21-A4
			3-5	IV25-A3	IV25-A3	
			6-9	IV25-A3	IV25-A3	
			2, 10-13	IV25-A5	IV25-A5	
			14, 15	IV25-A3	IV25-A5	
	Table IV.20 – Wood-Framed Floors with a Crawl Space Table IV.21 – Wood Framed Floors without a Crawl Space Table IV.22 – Wood Foam Panel (SIP) Floors Table IV.23 – Metal-Framed Floors with a Crawl Space	Other	1, 16	IV21-A4	IV21-A4	IV21-A4
			3-5	IV21-A2	IV21-A2	
			6-9	IV21-A2	IV21-A2	
			2, 10-13	IV21-A2	IV21-A2	

Type	ACM Joint Appendix IV Table	Class	Climate Zone	Non-residential	High Rise Residential and Hotel/Motel Guestrooms	Relocatable Classrooms
			Standard Design Construction Assembly			
	Table IV.24 – Metal-Framed Floors without a Crawl Space		14, 15	IV21-A2	IV21-A2	

2.3.2.1 Construction Identifiers

All constructions are selected from ACM Joint Appendix IV. Each construction is referenced by the table number and the column and row in the table.

2.3.2.2 Heat Capacity

Description

The ability of a construction assembly to absorb thermal energy. The heat capacity, HC, of an assembly is calculated by using the following equation:

Equation N2-1

$$HC = \sum_{i=1}^{n} (\rho_i \times c_i \times t_i)$$

where:

n is the total number of layers in the assembly

ρ_i is the density of the i^{th} layer

C_i is the specific heat of the i^{th} layer

t_i is the thickness of the i^{th} layer

all in consistent units.

HC is not an input to the reference program, nor is it used in the calculations. It is used, however to determine if a wall is medium mass or heavy mass or if a floor is medium or heavy mass. HC is reported in ACM Joint Appendix IV for wall construction assemblies, so it is generally not necessary to use the above equation to calculate HC.

DOE-2 Commands

LAYERS, MATERIAL

DOE-2 Keyword(s)

DENSITY
SPECIFIC-HEAT
THICKNESS

Input Type

HC is determined by the construction assembly choices for the proposed design. Each mass wall choice from ACM Joint Appendix IV has an HC value associated with it.

Tradeoffs

Neutral

Modeling Rules for Proposed Design

The ACM shall determine the overall heat capacity from the users choice of a construction assembly from ACM Joint Appendix IV.

Modeling Rules for Standard Design (All):

The construction assembly specified in Table N2-1 shall be used for the standard design.

2.3.2.3 Solar Reflectance and Thermal Emittance

Description

The combination of solar reflectance and thermal emittance are the reflective and radiative properties of exterior surfaces. A cool roof, as defined in the Standards, has a minimum initial solar reflectance of 0.70 and minimum initial emittance of 0.75, but with the performance method any combination of reflectance and emittance is recognized for credit or penalty.

- Absorptance is the fraction of the incident solar radiation absorbed as heat on the construction assembly's opaque exterior surface.
- Reflectance is the fraction of incident solar radiation that is reflected. Reflectance plus absorptance equal one.
- Thermal emittance is the ratio of radiant heat flux emitted by the construction assembly's opaque exterior surface to that emitted by a blackbody at the same temperature, hereafter referred to as "emittance."

DOE-2 Commands and Keywords

CONSTRUCTION	ABSORPTANCE ..
EXTERIOR-WALL	OUTSIDE-EMISS ..

Note that absorptance is equal to 1 – reflectance. The reference method accepts absorptance, but not reflectance.

Input Type: Required for roofs. Default for other surfaces.

Tradeoffs: Yes for roofs. No for other surfaces

Modeling Rules for Proposed Design: The reference method shall use an aged absorptance value to model the proposed design roof. The ACM shall calculate the aged absorptance, α_{aged}, from the following equation:

Equation N2-2 $$\alpha_{aged} = 0.8 + 0.7\ (\alpha_{init} - 0.8)$$

where α_{init} is the initial absorptance of the roofing product. The aged emittance shall be equal to the initial emittance.

There are two compliance cases, one for nonresidential roofs with low-slopes and the second for other nonresidential roofs, high-rise residential and hotel/motel roofs.

If values for reflectance or emittance other than the defaults are used, the roofing material shall be rated by the CRRC. If a non-default reflectance is used, then the default emittance may not be used.

Non-residential low-slope roofs - continuance variation of absorptance and emittance may be entered if the roofing product is rated by the CRRC and for liquid applied coatings if the requirements in Section 118 (i) 3 are met. The default value for roofs that are not rated by the CRRC or do not meet the requirements of Section 118 (i) 3 is 0.9 initial absorptance and 0.75 emittance for non-metallic surfaces and 0.20 for metallic surfaces, including but not limited to bare metal, galvanized steel and aluminum coating.

Other nonresidential roofs, high-rise residential and hotel/motel roofs - roofs that meet the requirements of Section 118 (i) 3 qualify for a compliance credit. Qualifying cool roofs shall model an initial absorptance of 0.30. Nonqualifying roofs shall use a default absorptance of 0.7. The default value for roofs that are not rated by the CRRC or do not meet the requirements of Section 118 (i) 3 is 0.75 emittance for non-metallic surfaces and 0.20 for metallic surfaces, including but not limited to bare metal, galvanized steel and aluminum coating.

The default values below shall be used for walls and floors and shall be the same as for the standard design.

Default: The default initial reflectance is 0.10 for nonresidential buildings with a low-slope roof and 0.30 for other roofs, including all high rise residential and hotel/motel guest rooms. The default emittance is 0.75. This default may not be used if a non-default reflectance is used.

Modeling Rules for Standard Design (All): The reference method shall use an aged absorptance value to model the standard design.

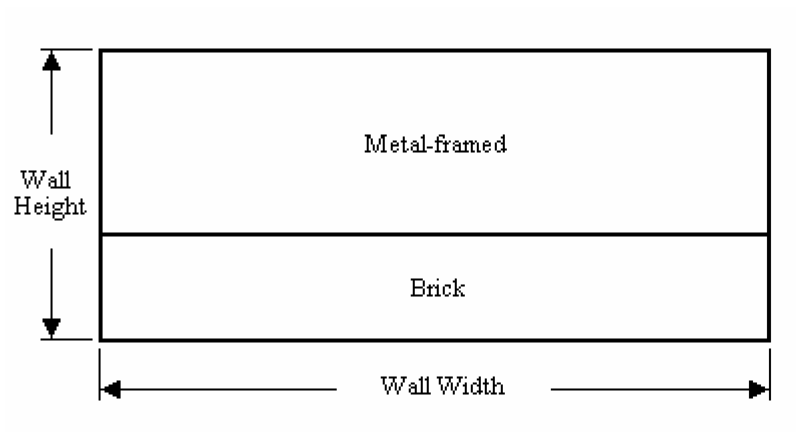
Nonresidential low-sloped roofs - the initial roof absorptance of the standard design shall be 0.30 (initial reflectance of 0.70). The emittance in the standard design shall be 0.75.

Other nonresidential roofs, high-rise residential and hotel/motel roofs - the initial roof absorptance of the standard design shall be 0.70. The emittance in the standard design shall be 0.75**.**

For all other roofs as well as walls and floors, the default reflectance and emittance shall be used.

2.3.2.4 Composite Walls

Description: Exterior wall assemblies that consist of more than one class of construction, i.e. any combination of wood framing, steel framing, masonry, and other types of wall construction assemblies. An example of a composite wall made up of a masonry section and a steel-framed section is shown below:



DOE-2 Command	EXTERIOR-WALL
DOE-2 Keyword(s)	LAYERS
Input Type	Required
Tradeoffs	Yes
Modeling Rules for Proposed Design:	The ACM shall model each type of construction in a composite wall shown in the construction documents as described above. The composite wall shall consist of multiple selections from ACM Joint Appendix IV, with each assigned an area.
Modeling Rules for Standard Design (New & Altered Existing):	Each part of the composite wall has a standard design construction which is defined in Table N2-1.
Modeling Rules for Standard Design (Existing Unchanged):	The standard design shall model each existing composite wall as it occurs in the existing building using the procedure described above. The existing construction assemblies shall be selected from ACM Joint Appendix IV.

2.3.3 Above-Grade Opaque Envelope

2.3.3.1 Exterior Partitions

Description:	Above-grade exterior partitions that separate conditioned spaces from the ambient air (outdoors), unconditioned attic spaces and crawl spaces, or courtyards. Exterior walls, raised floors, roofs, and ceilings are exterior partitions. The area of exterior partitions is defined by specifying the width of the partition and a height equal to the total height of the floor or by using another acceptable means such as specifying the vertices of a polygon.
DOE-2 Command	EXTERIOR-WALL
DOE-2 Keyword(s)	HEIGHT, WIDTH
Input Type	Required
Tradeoffs	Neutral
Modeling Rules for Proposed Design:	Each exterior partition shall be entered as it occurs in the construction documents.
Modeling Rules for Standard Design (All):	Exterior partitions in the standard design shall be identical to the proposed design.

2.3.3.2 Insulation Above Suspended Ceilings

Description	Section 118(e)3. of the Standard restricts the use of insulation over suspended ceilings. This is permitted only when the unconditioned space above the ceiling is greater than 12 ft and the insulted space shall be smaller than 2,000 ft².
Proposed Design	The proposed design may only use insulation over a suspended when the space qualifies for the exception to 118(e)3. The U-factor for the construction shall be selected from Table IV.8 from ACM Joint Appendix IV. Values from this table account for leakage through the suspended ceiling and discontinuity of the insulation.
Standard Design	The standard design roof construction shall be determined from Table N2-1, based on climate zone and class of construction. .

2.3.3.3 Surface Azimuth and Tilt of Exterior Partitions

Description:	The direction of an outward normal projecting from the partition's exterior surface relative to the true north. Positive azimuth is measured clockwise from the true north. Note: openings (doors and windows) inherit their azimuth and tilt from the parent surface.
DOE-2 Command	EXTERIOR-WALL
DOE-2 Keyword(s)	AZIMUTH TILT
Input Type	Required
Tradeoffs	Neutral
Modeling Rules for Proposed Design:	The azimuth and tilt of each exterior partition shall be input as shown in the construction documents for the building to the nearest whole degree.
Modeling Rules for Standard Design (All):	The azimuth and tilt of exterior partitions in the standard design shall be identical to those in the proposed design.

2.3.4 Interior Surfaces

2.3.4.1 Demising Partitions

Description	A barrier that separates a conditioned space from an enclosed unconditioned space. “Party walls” separating tenants, a partition separating a conditioned space from an unconditioned warehouse, and a glass partition separating a conditioned space from an unconditioned sunspace are examples of demising partitions.
DOE-2 Command	INTERIOR-WALL
DOE-2 Keyword(s)	HEIGHT WIDTH AZIMUTH TILT NEXT-TO
Input Type	Required
Tradeoffs	Neutral
Modeling Rules for Proposed Design:	The proposed design shall model demising partitions as adiabatic interior partitions. No heat transfer shall occur between the two adjacent spaces. ACMs shall require the user to input information for each demising partition including orientation and tilt, location, size, shape and construction as they occur in the construction documents. ACMs shall indicate in the compliance forms that demising partitions are used to separate the conditioned space from the unconditioned space. For framed demising partitions in a new construction, the compliance forms shall also indicate that R-11 insulation shall be installed.
Modeling Rules for Standard Design (All):	The standard design shall model each demising partition with the same thermal characteristics, orientation and tilt, location, size, shape and construction as the proposed design.

2.3.4.2 Interzone Walls

Description:	The reference method shall model heat transfer through interior walls separating directly conditioned zones from other directly and indirectly conditioned zones as air walls. The reference program accounts for the thermal mass of interior walls as described in Section 2.3.1.5.
DOE-2 Command	INTERIOR-WALL
DOE-2 Keyword(s)	WIDTH HEIGHT NEXT-TO
Input Type	Prescribed
Tradeoffs	Neutral
Modeling Rules for Proposed Design	ACMs shall receive inputs for the width and height (or area) of all interzone walls as they occur in the construction documents. The reference program shall model interzone walls as air walls with zero heat capacity and an overall U-factor of 1.0 Btu/h-ft^2-^{o}F.
Modeling Rules for Standard Design (All):	The reference method models all interzone walls as they occur (and as they are modeled) in the proposed design.

2.3.4.3 Interior Floors

Description:	The reference method shall model heat transfer through interior floors separating directly conditioned zones from other directly and indirectly conditioned zones.
DOE-2 Command	INTERIOR-WALL
DOE-2 Keyword(s)	WIDTH HEIGHT NEXT-TO
Input Type	Required
Tradeoffs	Neutral
Modeling Rules for Proposed Design:	ACMs shall receive inputs for all interior floors as they occur in the construction documents.
Modeling Rules for Standard Design (All):	The reference method models all interior as they occur (and as they are modeled) in the proposed design.

2.3.5 Fenestration and Doors

2.3.5.1 Area of Fenestration in Walls & Doors

Description: Fenestration surfaces include all glazing in walls and vertical doors of the building. The following inputs shall be received.

- *Fenestration Dimensions*. For each glazing surface, all ACMs shall receive an input for the glazing area. The reference method uses window width and height. The glazing dimensions are those of the rough-out opening for the window(s) or fenestration product. The area of the fenestration product will be the width times the height. For fenestration products with glazing surfaces on more than a single side such as garden windows, the ACM shall be able to accept entry for the dimensions of each side (glazing plus frame) with conditioned space on one side and unconditioned space on the other.
- *Field Fabricated Fenestration*. The area of field-fabricated fenestration cannot exceed 1,000 ft² when the building has more than 10,000 ft² of fenestration; buildings with more than 1,000 ft² do not comply. Also the use of less than 10,000 ft^2 of site-built fenestration in a building with more than 10,000 ft² of fenestration shall be reported in the exceptional conditions checklist.
- *Display Perimeter.* In a secondary menu (subordinate to the menu for fenestration area entries), the ACM shall allow the user to specify a value for the length of display perimeter, in feet, for each floor or story of the building. The user entry for Display Perimeter shall have a default value of zero. Note: Any non-zero input for Display Perimeter is an exceptional condition that shall be reported on the PERF-1 exceptional condition list and shall be reported on the ENV forms. The value for Display Perimeter is used as an alternate means of establishing Maximum Wall Fenestration Area in the standard design (Title 24, §143). Display perimeter is the length of an exterior wall in a B-2 occupancy that immediately abuts a public sidewalk, measured at the sidewalk level for each story that abuts a public sidewalk.
- *Floor Number.* The ACM shall also allow the user to specify the Display Perimeter associated with each floor (story) of the building.

DOE-2 Command	WINDOW
DOE-2 Keyword(s)	WIDTH

	HEIGHT
Input Type	Required
Tradeoffs	Yes
Modeling Rules for Proposed Design:	ACMs shall receive inputs for the proposed design fenestration width and height as they are documented on the construction documents.
Modeling Rules for Standard Design (New & Altered Existing):	The reference method calculates the maximum allowed fenestration area. This Maximum Wall Fenestration Area is 40% of the gross exterior wall area of the building that is conditioned when display perimeter is not specified. Also, the Maximum Wall Fenestration Area of the west-facing wall is 40% of the gross exterior west-facing wall area of the building that is conditioned when display perimeter is not specified.

If Display Perimeter is specified, the Maximum Wall Fenestration Area is either 40% of the gross exterior wall area of the building, or six feet times the Display Perimeter for the building, whichever value is greater. Also, if Display Perimeter is specified, the Maximum Wall Fenestration Area of the west-facing wall is 40% of the gross exterior west-facing wall area of the building, or six feet times the west-facing Display Perimeter for the building, whichever value is greater.

The reference method automatically calculates these two maximum fenestration areas for fenestration in walls and uses the greater of the two for the maximum total glazing area and maximum west facing glazing area of the reference building.

1. When the Window Wall Ratio in the proposed design is < 0.40 or < display perimeter × 6 feet, the standard design shall use the same wall fenestration height and width for each glazing surface of the proposed design exterior wall.
2. When the proposed design area of fenestration in walls and doors is greater than the maximum wall fenestration area described above, ACMs shall adjust the height and width of each glazing surface by multiplying them by a fraction equal to the square root of:

   Maximum Allowed Wall Fenestration Area/Total Proposed Fenestration Area.

For the standard design the area of each exterior wall construction shall equal the area of each exterior wall of the proposed design, except when the wall area of the proposed design exceeds the maximum allowable window-to-wall ratio (WWR). There are three cases, when the proposed design glazing exceeds the maximum allowable window-to-wall ratio (WWR), which shall be accounted for:

1. *One Wall Construction*. If the window occurs in a portion of wall where it abuts only one construction, the ACM shall decrease the glazing area to the allowable maximum and increase the area of the wall accordingly.
2. *Multiple Wall Constructions*. If the window occurs in a portion of wall where it abuts more than one construction in a given orientation, the ACM shall increase the area of each adjacent wall construction by the same proportion, as glazing area decreases.
3. *Propose WWR = 1.0*. If the Window-to-Wall Ratio, WWR, for any orientation or exterior surface is 1.0, the ACM shall calculate the area weighted average (AWA) HC for all of the walls of the proposed design to determine an HC for the hypothetical wall. The glazing amount is reduced and a wall is inserted as follows:
   a) AWA HC < 7.0 Btu/ft^2-^{o}F: The standard assembly is a steel-framed, lightweight wall with HC = AWA HC of the proposed walls and with a U-factor matching the requirement listed in Table 143-A, 143-B, or 143-C of

the Standards for other walls with HC < 7.0 and the applicable climate zone.

b) AWA HC ≥7.0 Btu/ft^2-^{o}F: The standard assembly is a homogeneous material with a U-factor matching the applicable value listed in Table 143-A, 143-B, or 143-C of the Standards for the applicable HC range and climate zone and the same HC as the proposed AWA HC.

Modeling Rules for Standard Design (Existing Unchanged): The standard design shall use the same fenestration area as the existing design.

2.3.5.2 Area of Fenestration in Exterior Roofs

Description: ACMs shall model the exposed surface area of fenestration in roofs separating those with transparent and translucent glazing. Such fenestration surfaces include all skylights or windows in the roofs including operable skylights and windows in the roofs of the building.

DOE-2 Command: ROOF

DOE-2 Keyword(s): WIDTH
HEIGHT

Input Type: Required

Tradeoffs: Yes

Modeling Rules for Proposed Design: ACMs shall receive inputs for width, length and height of each fenestration surface of the proposed design as they are shown in the construction documents. Surface area may also be described as vertices of a polygon.

Modeling Rules for Standard Design (New & Altered Existing): ACMs shall calculate the maximum allowed area of fenestration in roofs. This Maximum Roof Fenestration Area is 5% of the gross exterior roof area of the entire permitted space or building.

1. When the Skylight Roof Ratio (SRR) in the proposed design is < 0.05, for each roof fenestration, the standard design shall use the same skylight dimensions as the proposed design.

   EXCEPTION: When skylights are required by Section 143(c) (low-rise conditioned or unconditioned enclosed spaces that are greater than 25,000 ft^2 directly under a roof with ceiling heights greater than 15 ft and have a lighting power density for general lighting equal to or greater than 0.5 W/ft^2) and the SRR in the proposed design is less than the minimum, the standard design shall have a SRR of 3.0% for 0.5 W/ft^2 = LPD < 1.0 W/ft^2, 3.3% for 1.0 W/ft^2 = LPD < 1.4 W/ft^2, and 3.6% for LPD = 1.4 W/ft^2 in one half of the area of qualifying spaces.

2. When the Skylight Roof Ratio in the proposed design is > 0.05, the ACM shall adjust the dimensions of each roof fenestration of the standard design by multiplying them by a fraction equal to the square root of:

Equation N2-3 $$SRR_{standard}/SRR_{proposed}$$

Modeling Rules for Standard Design (Existing Unchanged): The standard design shall use the same fenestration area as the existing design.

2.3.5.3 Exterior Doors

Description:	Doors in exterior partitions.
DOE-2 Command	DOOR
DOE-2 Keyword(s)	WIDTH HEIGHT SETBACK MULTIPLIER
Input Type	Required.
Tradeoffs	Neutral
Modeling Rules for Proposed Design:	Users shall make a selection from ACM Joint Appendix IV. Other inputs shall include the area of each door and its position in the parent surface. Azimuth and tilt are typically inherited from the parent surface.
Modeling Rules for Standard Design (All):	The reference method shall model the exterior doors in a manner identical to the proposed design.

2.3.5.4 Product Identifiers

Description:	A unique alphanumeric identifier shall be used for each fenestration product. Separate identifiers shall be used to refer to proposed and standard designs of the same fenestration product. Each product shall be categorized as a manufactured fenestration product, a site-built fenestration product, or a field-fabricated fenestration. Any transparent or translucent material plus any sash, frame, mullions, and dividers, in the envelope of a building, including, but not limited to: windows, sliding glass doors, French doors, skylights, curtain walls, and garden windows. Windows include not only common windows but also all fenestration products in the walls of the building envelope. Examples of such fenestration products include all windows and glazing materials, glass block walls, translucent panels, and glass doors. Walls are portions of the building envelope with tilts from vertical to less than 30 degrees from vertical.
DOE Keyword:	WINDOW
Input Type:	Required
Tradeoffs	Yes

2.3.5.5 Fenestration Orientation and Tilt

Description:	The reference method models the actual azimuth (direction) and surface tilt of windows and skylights (fenestration products) in each wall and roof surface. In the reference method, these window properties are inherited from the parent surface in the reference method.
Modeling Rules for Proposed Design:	Azimuth and surface tilt of each glazing surface shall be input as they occur in the construction documents.
Modeling Rules for Standard Design (All):	Azimuth and surface tilt of each glazing surface shall be the same as they occur in the proposed design.

2.3.5.6 Fenestration Thermal Properties

Description:	ACMs shall model the overall U-factor and Solar Heat Gain Coefficient (SHGC) for

each fenestration assembly, including inside and outside air films and effects of framing, spacers and other non-glass materials as applied to the full rough-out fenestration area. ACMs shall require the user to indicate the source of the U-factor and SHGC: Acceptable sources are NFRC label values, default values from Tables 116-A and 116-B, or alternate default values from the ACM Appendix.

In this Section the word "Window" is used to refer to fenestration in a surface that has a tilt greater than 60 degrees from the horizontal.

DOE-2 Command: WINDOW

DOE-2 Keyword(s): FRAME-CONDUCTANCE
FRAME-WIDTH
FRAME-ABS

Input Type: Required

Tradeoffs: Yes

Modeling Rules for Proposed Design:

The reference program uses a FRAME ABSORPTANCE of 0.70.

ACMs shall receive inputs for or determine the default for the U-factor and SHGC of each fenestration product of system in the proposed design.

NFRC label values are allowed for all fenestration categories. If the user selects "NFRC labeled values" for a particular fenestration product, the ACM shall receive values for the U-factor and SHGC. Use the following rules:

- For manufactured vertical fenestration, the default values shall be the U-factor and SHGC listed in Table 116-A and Table 116-B of the Standard.
- For site-built fenestration products in buildings with 10,000 square feet or more of site-built fenestration, the default values shall be the U-factor and SHGC listed in Tables 116-Aand 116-B of the Standards.
- For site-built fenestration products in buildings with less than 10,000 square feet of site-built fenestration, the default values shall be the alternate default U-factor and SHGC using the defaults and calculations specified in ACM Appendix NI or the U-factor and SHGC listed in Table 116-A and Table 116-B of the Standard.
- For skylights, the default values shall be the alternate default U-factor and SHGC using default calculations specified in Appendix NI or the U-factor and SHGC listed in Table 116-A and Table 116-B of the Standard.
- For field-fabricated fenestration, the default values shall be the U-factor and SHGC listed in Tables 116-A and 116-B of the Standard. The use of this field fabricated fenestration or field-fabricated exterior doors is an exceptional condition that shall be reported in the exceptional conditions checklist.

Modeling Rules for Standard Design (New & Altered Existing): ACMs shall use the appropriate "Maximum U-factor " and RSHG or SHGC for the window as appropriate from Tables 143-A, 143-B, and 143-C of the Standards including the framing according to the occupancy type and the climate zone. The standard design uses a FRAME ABSORPTANCE of 0.70.

Modeling Rules for Standard Design (Existing Unchanged): The standard design shall use the existing design's U-factor and SHGC or RSHG as appropriate including the framing. The standard design uses a FRAME ABSORPTANCE of 0.70.

2.3.5.7 Solar Heat Gain Coefficient of Fenestration in Walls & Doors

Description: The reference method models the solar heat gain coefficient (SHGC) of glass including the framing, dividers, and mullions. The shading effects of dirt, dust, and degradation are purposely neglected and an ACM user may not adjust solar heat gain coefficients because of these effects. The ACM user's manual shall reflect these restrictions on user entries.

If the user has specified Display Perimeter, ACMs may also receive an input in a subordinate menu for the Relative Solar Heat Gain (RSHG) requirement except for cases where local building codes prohibit or limit the use of overhangs or exterior shading devices. The use of this RSHG exception input is itself an exceptional condition that shall be reported in the exceptional conditions checklist of the PERF-1 form.

DOE Keyword: SHADING-COEF

Input Type: Required

Tradeoffs: Yes

Modeling Rules for Proposed Design: Fenestration solar heat gain coefficient (SHGC) for each fenestration surface shall be input as it occurs in the construction documents for the building. ACMs that require inputting shading coefficient (SC) instead of SHGC shall calculate the fenestration's shading coefficient using the following formula:

Equation N2-4 $SC_{fenestration} = SHGC/0.87$

Note: This equation is taken from Blueprint #57, dated Fall 1996. Since both SC for nonresidential buildings and SHGC apply to the entire rough-out opening, the adjustment for framing and divider has been removed.

Modeling Rules for Standard Design (New & Altered Existing): ACMs shall use the appropriate maximum RSHG values from Tables 143-A, 143-B, and 143-C of the Standards according to occupancy, climate zone, window wall ratio and orientation as the standard design solar heat gain coefficient. The maximum RSHG is different for north-oriented glass; for the purposes of establishing standard design solar heat gain coefficient, north glass is glass in walls facing from 45° west (not inclusive) to 45° east (inclusive) of true north.

If the user has claimed the RSHG exception for a section of display perimeter, the standard design uses the maximum RSHG for north glass found in Tables 143-A, 143-B, and 143-C of the Standards for any fenestration surface utilizing this exception.

Modeling Rules for Standard Design (Existing Unchanged): The standard design shall use the same RSHG value as the existing design including the framing.

2.3.5.8 Solar Heat Gain Coefficient of Fenestration in Roofs

Description: The reference method models the solar heat gain coefficient of the fenestration including the glass and framing. The shading effects of dirt, dust, and degradation are purposely neglected and an ACM user may not adjust solar heat gain coefficients because of these effects. The ACM user's manual shall reflect these restrictions on user entries.

DOE-2 Command

DOE-2 Keyword(s) SHADING-COEF

Input Type Required

Tradeoffs Yes

Modeling Rules for Proposed Design: Fenestration solar heat gain coefficient for each fenestration surface in the roof(s) of a building or permitted space shall be input as it occurs in the construction documents for the building or permitted space. ACMs that require inputting shading coefficient (SC) instead of SHGC shall calculate the fenestration's shading coefficient using the following formula:

Equation N2-5 $$SC_{fenestration} = SHGC/0.87$$

Note: This equation is taken from Blueprint #57, dated Fall 1996. Since both SC for nonresidential buildings and SHGC apply to the entire rough-out opening, the adjustment for framing and divider has been removed.

Modeling Rules for Standard Design (New & Altered Existing): ACMs shall use the appropriate maximum solar heat gain coefficient from Tables 143-A, 143-B, and 143-C of the Standards according to the occupancy type, the climate zone and the fenestration type.

Modeling Rules for Standard Design (Existing Unchanged): The standard design shall use the same SHGC value as the existing design.

2.3.5.9 Overhangs

Description: ACMs shall be capable of modeling overhangs over windows and shall have the following inputs:

- *Overhang position.* The distance from the edge of the window to the edge of the overhang.
- *Height above window.* The distance from the top of the window to the overhang.
- *Overhang Width*. The width of the overhang parallel to the plane of the window.
- *Overhang extension*. The distance the overhang extends past the edge of the window jams.
- *Overhang Angle.* The angle between the plane of window and the plane of the overhang.

DOE-2 Command WINDOW

DOE-2 Keyword(s) OVERHANG-A
OVERHANG-B
OVERHANG-W
OVERHANG-D
OVERHANG-ANGLE

Input Type Default

Tradeoffs Yes

Modeling Rules for Proposed Design: Overhangs shall be modeled in the proposed design for each window as they are shown in the construction documents.

Default: No overhang.

Modeling Rules for Standard Design (New & Altered Existing): No overhang.

Modeling Rules for Standard Design (Existing Unchanged):	Overhangs shall be modeled in the same manner as they occur in the existing design.

2.3.5.10 Vertical Shading Fins

Description: ACMs shall be capable of modeling vertical fins. Vertical fins shall affect the solar gain of fenestration products only. ACMs shall have the following inputs:

- *Wall/window.* Input shall require the user to specify the wall/or window with which the fin is associated.
- *Horizontal position.* The distance from the outside edge of the window to the fin.
- *Vertical position.* The distance from the top edge of the fin to the top edge of the window.
- *Fin height*. The vertical height of the fin.
- *Depth.* The depth of the fin, measured perpendicularly from the wall to the outside edge of the fin.

DOE-2 Command	WINDOW
DOE-2 Keyword(s)	LEFT-FIN-A RIGHT-FIN-A LEFT-FIN-B RIGHT-FIN-B LEFT-FIN-H RIGHT-FIN-H LEFT-FIN-D RIGHT-FIN-D
Input Type	Default
Tradeoffs	Yes, except for pre-existing vertical fins in existing buildings.
Modeling Rules for Proposed Design:	Vertical fins shall be modeled in the proposed design for each window as they are shown in the construction documents.
Default	No vertical fins
Modeling Rules for Standard Design (New & Altered Existing):	No vertical fins
Modeling Rules for Standard Design (Existing Unchanged):	Vertical fins shall be modeled in the same manner as they occur in the existing design.

2.3.5.11 Exterior Fenestration Shading Devices

Description:	ACMs shall be able to model exterior fenestration shading devices which affect the solar gain of glazing surfaces. Overhangs and side fins are not considered exterior devices in this context. .
DOE-2 Command	N/A
DOE-2 Keyword(s)	N/A
Input Type	Default
Tradeoffs	Yes

Modeling Rules for Proposed Design:	Exterior fenestration shading devices shall be modeled in the proposed design for each window as they are shown in the construction documents. Note: Applications of Exterior Shading Devices are very limited; see Section 4.3.4.9 for restrictions on modeling Exterior Shading Devices.
Default:	No exterior fenestration shading devices
Modeling Rules for Standard Design (New & Altered Existing):	Exterior fenestration shading devices shall not be modeled in the standard design; however, the fenestration shall meet the prescriptive requirements for U-factor and solar heat gain coefficient.
Modeling Rules for Standard Design (Existing Unchanged):	Exterior fenestration shading devices shall be modeled in the same manner as they occur in the existing design.

2.3.5.12 Window Management

Description:	The reference method simulates window management/interior shading devices in the following manner. ACMs may either use this method or a method yielding equivalent results. Window solar heat gain coefficient is multiplied by a multiplier which gives the effective solar heat gain coefficient for combined shading device and window when the shading device covers the window.
DOE-2 Command	
DOE-2 Keyword(s)	SHADING-SCHEDULE. Use the DOE-2 window management algorithms and close the default drapes or internal shade when solar gain through the window exceeds 30 Btu/h-ft². Otherwise open the default internal shade.
Input Type	Prescribed
Tradeoffs	Neutral
Default	The default internal shade shall reduce solar gains by 20% (a multiplier of 0.80) when the drapes are closed.
Modeling Rules for Proposed Design:	The proposed design shall use the default shade and window management.
Modeling Rules for Standard Design (All):	The standard design models the same window management as the proposed design.

2.3.6 Below-Grade Envelope

2.3.6.1 Underground Walls

Description:	Underground walls separate a conditioned space from the adjacent soil or bedrock.
DOE-2 Command	UNDERGROUND-WALL
DOE-2 Keyword(s)	WIDTH HEIGHT
Input Type	Prescribed
Tradeoffs	Neutral

Modeling Rules for Proposed Design:	The reference method shall model below grade walls using UNDERGROUND-WALL Keyword using their actual construction, input by the user, with an additional one-foot layer of earth coupled to the ground temperature. ACMs shall set the effective U-factor of underground walls to zero The reference method shall assume soil layers to have a thermal conductivity of 0.50 Btu-ft/h-ft^2-^{o}F and a density of 85 lb/ft³. Concrete is assumed to have a thermal conductivity of 0.758 Btu-ft/h-ft^2-^{o}F and a density of 140 lb/ft³. The reference method assumes that both soil and concrete have a specific heat of 0.20 Btu/lb-^{o}F. If the proposed design has an insulated slab, then heat loss from the slab shall be approximated by entering an exterior wall and assigning an area to the wall equal to the exposed perimeter of the slab. The U-factor of the exterior wall shall be the F-factor for the proposed design selected from ACM Joint Appendix IV, Table IV-26 and modeled according to the rules with Table IV-26.
Modeling Rules for Standard Design (All):	ACMs shall model underground walls in the standard design exactly the same as they are modeled in the proposed design, including construction, area and position. The slab perimeter (the area of the hypothetical exterior wall described for the proposed design) shall be the same for the standard design and the U-factor of this hypothetical exterior wall shall be the F-factor from IV26-A1 and modeled according to the rules with Table IV-26.

2.3.6.2 Underground Concrete Floors

Description:	Underground concrete floors separate a conditioned space from the adjacent soil or bedrock.
DOE-2 Command	UNDERGROUND-FLOOR
DOE-2 Keyword(s)	WIDTH HEIGHT
Input Type	Prescribed
Tradeoffs	Neutral
Modeling Rules for Proposed Design:	ACMs shall model underground floor constructions and areas input as they occur in the construction documents along with a one-foot layer of soil beneath the floor. ACMs shall set the effective U-factor of underground floors to zero. The reference method shall assume soil layers to have a thermal conductivity of 0.50 Btu-ft/h-ft^2-ºF and a density of 85 lb/ft³. Concrete is assumed to have a thermal conductivity of 0.7576 Btu-ft/h-ft^2-ºF and a density of 140 lb/ft³. The reference method assumes that both soil and concrete have a specific heat of 0.20 Btu/lb-ºF.
Modeling Rules for Standard Design (All):	The standard design shall use the same underground floor constructions, areas, and position as the proposed design.

2.4 Building Occupancy

The user of an ACM shall be able to select an occupancy type from certain allowed tables. ACMs that do not have separate selection lists for ventilation occupancy assumptions and all other occupancy assumptions shall allow the user to select from the occupancies listed in Table N2-2 and Table N2-3 or to select from an officially approved alternative sub-occupancy list that maps into those occupancies. ACMs that have separate occupancy selection lists for ventilation assumptions and other assumptions shall use the occupancy selections given in tables in the Building Energy Efficiency Standards or approved alternative lists of occupancies. The occupancies listed in Table 121-A in the Standards shall be used for ventilation occupancy selections and the occupancies listed in Table 146-D in the Standards shall be used for selecting the remaining occupancy assumptions. Alternatively specific occupancy selection lists approved by the Commission that map into Tables 121-A or 146-D may be used.

A building consists of one or more occupancy types. ACMs cannot combine different occupancy types. Table N2-2 and Table N2-3 describe all of the schedules and full load assumptions for occupants, lighting, infiltration, receptacle loads and ventilation. Full load assumptions are used for both the proposed design and the standard design compliance simulations.

2.4.1 Assignment

2.4.1.1 Occupancy Types

Description

A modeled building shall have at least one defined occupancy type. A default occupancy of "all other" may be used to fulfill this requirement. Alternative Calculation Methods (ACMs) shall model the following occupancy types for buildings and spaces when lighting compliance is not performed or lighting plans are submitted for the entire building. Occupancies that are considered as subcategories of these occupancies are listed in Table N2-2 of this manual. ACMs with default occupancies shall use the "all other" occupancy category as a default.

When lighting plans are submitted for portions or for the entire building or when lighting compliance is not performed, Alternative Calculation Methods (ACMs) shall model the following area occupancy types for spaces within an HVAC zone. These area occupancy types are listed in Table N2-3 of this manual. (Note: Some additional area occupancies are listed as subcategories of the area occupancies listed in Table N2-3):

Please note that this list is comprehensive given the categories "all other." Occupancies and area occupancies other than those listed herein cannot be approximated by another occupancy or area occupancy unless that substitution has been approved by the Executive Director of the Commission in writing.

The selection lists accommodate unknown or miscellaneous unlisted occupancies. Any space that will be leased to an unknown tenant is considered “tenant lease space.” Other occupancies unknown to the applicant and any known occupancy not reasonably similar (as determined by the local building official) to an occupancy specified on a Commission-approved list is considered "all other."

DOE-2 Command: SPACE

DOE-2 Keyword(s): SPACE-CONDITIONS

Input Type: Required

Tradeoffs: Neutral

Modeling Rules for Proposed Design:

ACMs shall require users to specify the occupancy of the building or the area occupancy of each zone being modeled. ACMs shall require the user to identify if lighting compliance is performed (lighting plans are included or have already been submitted). ACMs shall determine the occupancy type as follows:

- *Lighting compliance not performed*. The ACM shall require the user to select the occupancy type(s) for the building from the occupancies reported in Table N2-2 or Table 146-C of the Standards. The ACM shall use the occupancy assumptions of this Table for compliance simulations.
- *Lighting compliance performed*. The ACM shall require the user to select the occupancy type(s) for each zone from the occupancies reported in Table N2-3 or Table 146-C of the Standards. The ACM shall use the area occupancy assumptions from Table N2-3 for compliance simulations.

Tailored lighting and tailored ventilation are permitted as exceptional condition modifications to these default assumptions, but shall be reported on the PERF-1 as exceptional conditions and on other applicable compliance forms. Only the general lighting may be traded off in the performance method. Use-it-or-lose-it lighting power allowances may not be traded off; these shall be the same for both the standard design and the proposed design.

ACMs shall use the same default assumptions, listed in Table N2-2 through Table N2-7 of this manual including schedules, occupant densities, outside air ventilation rates, lighting loads, receptacle loads and service water heating loads. ACMs may have a separate occupancy list for ventilation versus other assumptions subject to the constraint that occupancy schedule types cannot be mixed. Users shall select occupancy of a given space based upon the proposed or anticipated occupancy not on the amount of lighting desired. ACM input shall emphasize occupancy choices and similarities not lighting choices. ACMs may not report the occupancy default lighting watts per square foot on the screen when the user is selecting occupancies for a space. After the occupancies are selected by the user, the lighting determined from the user's occupancy selection may appear on a separate entry screen as a default entry in the lighting power input if the user has not already entered it.

Modeling Rules for Standard Design (All): ACMs shall model the same occupancy type(s) and area occupancy type(s) as the proposed building. ACMs shall use the same default assumptions found in Table N2-2 through Table N2-7. Tailored lighting and tailored ventilation are permitted as a modification to these default assumptions but shall be reported on the PERF-1 exceptional condition list. Refer to sections for Lighting, Ventilation, and Process Loads for respective requirements for each of these adjustments.

2.4.1.2 Mixed Area Occupancies

Description: ACMs shall allow the user to select mixed as the occupancy type when selecting an area occupancy for each zone. This option shall only be available if lighting compliance is performed (lighting plans are (or have been) submitted for the zone). Refer to Chapter 4 for restrictions on selecting mixed as the area occupancy type.

DOE-2 Command: SPACE

DOE-2 Keyword(s): SPACE-CONDITIONS

Input Type: Required

Tradeoffs: Neutral

Modeling Rules for Proposed Design: The ACM shall request input for the following:

1. Total area of the space
2. Area and occupancy type of different area occupancy types; however, the subareas may also be optionally entered as percentages of the total area

The ACM shall automatically calculate the sum of the areas for the different occupancies:

- If the sum of the different areas (or percentages) is greater than the input total area of the space, the ACM shall require corrected input or proportionately scale down the entries so that the sum is the total area.
- If the sum of the different occupancies is less than the input total area, the ACM shall assign the occupancy other to the area needed to equal the input total area.

The ACM shall assign occupancy-determined assumptions for occupant densities, outside air ventilation rates, lighting loads, receptacle loads and service water heating loads by calculating the area-weighted average for each of these inputs, using the areas input by the user. Refer to sections for Lighting, Ventilation, and Process Loads for respective requirements for each of these adjustments.

ACMs shall not allow input of subarea occupancies with different schedules (e.g. Nonresidential, Residential or Retail) within the same mixed area occupancy. However, "Corridor, Restroom, and Support Area" spaces may be part of a mixed occupancy and use the schedule of the other occupancies making up the mixed occupancy zone rather than the default schedule assigned to this occupancy type.

Modeling Rules for Standard Design (All): ACMs shall use the same default assumptions calculated for the proposed design, as well as any tailored lighting, tailored ventilation, and receptacle loads input for the proposed design.

Table N2-2 – Occupancy Assumptions When Lighting Plans are Submitted for the Entire Building or When Lighting Compliance is not Performed

Occupancy Type	#people per 1000 ft^2(1)	Sensible Heat per person(2)	Latent Heat per person(2)	Receptacle Load W/ft^2(3)	Hot Water Btu/h per person	Lighting W/ft^2(4)	Ventilation CFM/ft^2(5)
Auditoriums (Note 8)	143	245	105	1.0	60	1.5	1.07
Convention Centers (Note 8)	136	245	112	0.96	57	1.3	1.02
Financial Institutions	10	250	250	1.5	120	1.1	0.15
General Commercial and Industrial Work Buildings, High Bay	7	375	625	1.0	120	1.1	0.15
General Commercial and Industrial Work Buildings, Low Bay	7	375	625	1.0	120	1.0	0.15
Grocery Stores (Note 8)	29	252	225	0.91	113	1.5	0.22
Hotel(6)	20	250	200	0.5	60	1.4	0.15
Industrial and Commercial Storage Buildings	5	268	403	0.43	108	0.7	0.15
Medical Buildings and Clinics	10	250	213	1.18	110	1.1	0.15
Office Buildings	10	250	206	1.34	106	1.1	0.15
Religious Facilities (Note 8)	136	245	112	0.96	57	1.6	1.03
Restaurants (Note 8)	45	274	334	0.79	366	1.2	0.38
Retail and Wholesale Stores (Note 8)	29	252	224	0.94	116	1.5	0.22
Schools (Note 8)	40	246	171	1.0	108	1.2	0.32
Theaters (Note 8)	130	268	403	0.54	60	1.3	0.98
All Others	10	250	200	1.0	120	0.6	0.15

(1) Most occupancy values are based on an assumed mix of sub-occupancies within the area. These values were based on one half the maximum occupant load for exiting purposes in the CBC. Full value for design conditions. Full year operational schedules reduce these values by up to 50% for compliance simulations and full year test simulations.

(2) From Table 1, p. 29.4, ASHRAE 2001Handbook of Fundamentals

(3) From Lawrence Berkeley Laboratory study. This value is fixed and includes all equipment that are plugged into receptacle outlets.

(4) From Table 146-B of the Standards for the applicable occupancy. The lighting power density of the standard building, for areas where no lighting plans or specifications are submitted for permit and the occupancy of the building is not known, is 1.2 watts per square foot.

(5) Developed from Section 121 and Table 121-A of the Standards

(6) Hotel uses values for Hotel Function Area from Table N2-3.

(7) For retail and wholesale stores, the complete building method may only be used when the sales area is 70% or greater of the building area.

(8) For these occupancies, when the proposed design is required to have demand control ventilation by Section 121 (c) 3 the ventilation rate is the minimum that would occur at any time during occupied hours. Additional ventilation would be provided through demand controlled ventilation to maintain CO_2 levels according to Section 121 of the Standards.

Table N2-3 – Area Occupancy Assumptions When Lighting Plans are Submitted for Portions or for the Entire Building or When Lighting Compliance is not Performed

Sub-Occupancy Type (1)	People per 1000 ft^2 (2)	Sensible heat per person(3)	Latent heat per person(3)	Receptacle Load W/ft^2 (4)	Hot water Btu/hper person	Lighting W/ft^2 (5)	Ventilation CFM/ ft^2 (6)
Auditorium (Note 10)	143	245	105	1.0	60	1.5	1.07
Auto Repair	10	275	475	1.0	120	1.1	1.50
Bar, Cocktail Lounge and Casino (Note 10)	67	275	275	1.0	120	1.1	0.50
Barber and Beauty Shop	10	250	200	2.0	120	1.0	0.40
Classrooms, Lecture, Training, Vocational Room	50	245	155	1.0	120	1.2	0.38
Civic Meeting Space (Note 10)	25	250	200	1.5	120	1.3	0.19
Commercial and Industrial Storage	3	275	475	0.2	120	0.6	0.15
Convention, Conference, Multi-purpose and Meeting Centers (Note 10)	67	245	155	1.0	60	1.4	0.50
Corridors, Restrooms, Stairs, and Support Areas	10	250	250	0.2	0	0.6	0.15
Dining (Note 10)	67	275	275	0.5	385	1.1	0.50
Electrical, Mechanical Room	3	250	250	0.2	0	0.7	0.15
Exercise, Center, Gymnasium	20	255	875	0.5	120	1.0	0.15
Exhibit, Museum (Note 10)	67	250	250	1.5	60	2.0	0.50
Financial Transaction	10	250	250	1.5	120	1.2	0.15
Dry Cleaning (Coin Operated)	10	250	250	3.0	120	0.9	0.30
Dry Cleaning (Full Service Commercial)	10	250	250	3.0	120	0.9	0.45
General Commercial and Industrial Work, High Bay	10	275	475	1.0	120	1. 1	0.15
General Commercial and Industrial Work, Low Bay	10	275	475	1.0	120	1.0	0.15
General Commercial and Industrial Work, Precision	10	250	200	1.0	120	1. 3	0.15
Grocery Sales (Note 10)	33	250	200	1.0	120	1.6	0.25
High-Rise Residential Living Spaces (9)	5	245	155	0.5	(7)	0.5	0.15
Hotel Function Area (Note 10)	67	250	200	0.5	60	1.5	0.50
Hotel/Motel Guest Room(9)	5	245	155	0.5	2800	0.5	0.15
Housing, Public and Common Areas, Multi-family	10	250	250	0.5	120	1.0	0.15
Housing, Public and Common Areas, Dormitory, Senior Housing	10	250	250	0.5	120	1.5	0.15
Kitchen, Food Preparation	5	275	475	1.5	385	1.6	0.15
Laundry	10	250	250	3.0	385	0.9	0.15
Library, Reading Areas	20	250	200	1.5	120	1.2	0.15
Library, Stacks	10	250	200	1.5	120	1.5	0.15
Lobby, Hotel	10	250	250	0.5	120	1.1	0.15
Lobby, Main Entry	10	250	250	0.5	60	1.5	0.15
Locker/Dressing Room	20	255	475	0.5	385	0.8	0.15
Lounge, Recreation (Note 10)	67	275	275	1.0	60	1.1	0.50
Malls and Atria (Note 10)	33	250	250	0.5	120	1.2	0.25
Medical and Clinical Care	10	250	200	1.5	160	1.2	0.15
Office	10	250	200	1.5	120	1.2	0.15
Police Station and Fire Station	10	250	200	1.5	120	0.9	0.15
Religious Worship (Note 10)	143	245	105	0.5	60	1.5	1.07
Retail Merchandise Sales, Wholesale Showroom (Note 10)	33	250	200	1.0	120	1.7	0.25

Tenant Lease Space	10	250	200	1.5	120	1.0	0.15
Theater, Motion Picture) (Note 10)	143	245	105	0.5	60	0.9	1.07
Theater, Performance) (Note 10)	143	245	105	0.5	60	1.4	1.07
Transportation Function (Note 10)	33	250	250	0.5	120	1.2	0.25
Waiting Area	10	250	250	0.5	120	1.1	0.15
All Other	10	250	200	1.0	120	0.6	0.15

(1) Subcategories of these suboccupancies are described in Section 2.4.1.1 (Occupancy Types) of this manual.

(2) Values based on one half the maximum occupant load for exiting purposes in the CBC. Full value for design conditions. Full year operational schedules reduce these values by up to 50% for compliance simulations and full year test simulations.

(3) From Table 1, p. 29.4, ASHRAE 2001 Handbook of Fundamentals.

(4) From Lawrence Berkeley Laboratory study. This value is fixed and includes all equipment that are plugged into receptacle outlets.

(5) From Table 146-C of the Standards for the applicable occupancy. ACMs shall use this value for the standard building design when lighting compliance is performed for the zone or area in question.

(6) Developed from Section 121 and Table 121-A of the Standards.

(7) Refer to residential water heating method.

(8) The use of this occupancy category is an exceptional condition that shall appear on the exceptional conditions checklist and thus requires special justification and documentation and independent verification by the local enforcement agency.

(9) For hotel/motel guest rooms and high-rise residential living spaces all these values are fixed and are the same for both the proposed design and the standard design. ACMs shall ignore user inputs that modify these assumptions for these two occupancies. Spaces in high-rise residential buildings other than living spaces, shall use the values for Housing, Public and Common Areas (either multi-family or senior housing).

(10) For these occupancies, when the proposed design is required to have demand control ventilation by Section 121 (c) 3 the ventilation rate is the minimum that would occur at any time during occupied hours. Additional ventilation would be provided through demand controlled ventilation to maintain CO_2 levels according to Section 121 of the Standards.

2.4.1.3 Occupant Loads

Description: Based on the occupancy or area occupancy type(s) input by the user, ACMs shall determine the correct occupant density and sensible and latent heat gain per occupant.

DOE-2 Command: SPACE

DOE-2 Keyword(s):
PEOPLE-SCHEDULE
AREA/PERSON
PEOPLE-HG-SENS
PEOPLE-HG-LAT

Input Type: Prescribed

Tradeoffs: Neutral

Modeling Rules for Proposed Design: The ACM shall determine the correct occupant load and sensible and latent heat gain per occupant from Table N2-2 or Table N2-3.

Modeling Rules for Standard Design (All): The standard design shall use the same occupant density and sensible and latent heat gain per occupant as the proposed design.

2.4.1.4 Receptacle Loads

Description: Based on the occupancy or area occupancy type(s) input by the user, ACMs shall determine the correct receptacle load for each occupancy type.

The receptacle load includes all equipment that are plugged into receptacle outlets. For an office occupancy the receptacle load includes all plugged-in office equipment including computer CPUs, computer monitors, workstations, and printers.

DOE-2 Command	SPACE
DOE-2 Keyword(s)	EQUIPMENT-W/SQFT EQUIP-SCHEDULE
Input Type	Prescribed
Tradeoffs	Neutral
Modeling Rules for Proposed Design:	The ACM shall determine the correct receptacle load from Table N2-2 or Table N2-3.
Modeling Rules for Standard Design (All):	The standard design shall use the receptacle load of the proposed design.

2.4.1.5 Process Loads

Description:	Process load is the internal energy of a building resulting from an activity or treatment not related to the space conditioning, lighting, service water heating, or ventilating of a building as it relates to human occupancy. Process load may include sensible and/or latent components. ACMs shall model and simulate process loads only if the amount of the process energy and the location and type of process equipment are specified in the construction documents. These information shall correspond to specific special equipment shown on the building plans and detailed in the specifications. The ACM Compliance Documentation shall inform the user that the ACM will output process loads including the types of process equipment and locations on the compliance forms. ACMs shall use the Equipment Schedules from Tables N2-4, N2-5, N2-6, N2-7, or N2-8 for the operation of process equipment based on the occupancy type selected by the user.
DOE-2 Command	SPACE
DOE-2 Keyword(s)	SOURCE-TYPE SOURCE-BTU/HR SOURCE-SENSIBLE SOURCE-LATENT
Input Type	Default
Tradeoffs	Neutral
Modeling Rules for Proposed Design:	ACMs shall receive input for Sensible and/or Latent Process Load for each zone in the proposed design. The process load input shall include the amount of the process load (W/ft^2), the type of process equipment, and the HVAC zone where the process equipment is located. The modeled information shall be consistent with the plans and specifications of the building.
Default:	No Process Loads
Modeling Rules for Standard Design (All):	The standard design shall use the same process loads for each zone as the proposed design.

2.4.1.6 Infiltration

Description:	ACMs shall model infiltration of outdoor air through exterior surfaces.
DOE-2 Command	SPACE

DOE-2 Keyword(s)	INF-SCHEDULE INF-METHOD AIR-CHANGES/HR
Input Type	Prescribed
Tradeoffs	Neutral
Modeling Rules for Proposed Design:	Infiltration shall either be modeled as "ON" or "OFF", for each zone, according to the following: • "OFF" if fans are ON and zone supply air quantity (including transfer air) is greater than zone exhaust air quantity. • "ON" if fans are OFF. When infiltration is "ON", the reference method calculates the infiltration rate as 0.038 cfm per square foot of gross exterior partition (walls and windows) area for the zone.
Modeling Rules for Standard Design (All):	ACMs shall model infiltration for the standard design exactly the same as the proposed design.

2.4.2 Lighting Power

2.4.2.1 Outdoor Lighting

With the 2005 Standards, outdoor lighting is regulated and the requirements are contained in Section 147. Outdoor lighting shall not be considered in performance calculations. There are no tradeoffs between outdoor lighting and interior lighting, HVAC or water heating energy. ACMs shall not include outdoor lighting in the TDV energy budget or the TDV energy for the proposed design.

2.4.2.2 Interior Lighting

Description

ACMs shall model lighting for each space. Lighting loads shall be included as a component of internal heating loads. ACMs shall allocate 100% of the lighting heat to the space in which the lights occur.

ACMs shall receive an input to indicate one of the following conditions for the building:

1. *Lighting compliance not performed.* When the user indicates with the required ACM input that no lighting compliance will be performed, the ACM shall require the user to select and input the occupancy type(s) of the building from Table N2-2 or Table N2-3. The ACM shall determine the lighting levels based on the selected occupancy type(s). An ACM shall not allow the user to input any lighting power densities for the building.

   NOTE: ACMs may use Table N2-2 even if the building has multiple occupancies.

2. *Lighting compliance performed.* When the user indicates with that lighting compliance will be performed and lighting plans will be submitted for the entire building (excluding the residential units of high-rise residential buildings and hotel/motel guest rooms), the ACM shall require the user to select and input the occupancy type(s) from Table N2-2 or Table N2-3and enter the proposed interior lighting equipment or interior lighting power density (LPD) for each space that is modeled. Proposed design use-it-or-loose-it lighting power shall be entered separately from the general lighting. However, if lighting plans will be

submitted only for portions of the building, the ACM shall require the user to select and input the occupancy type(s) from Table N2-3and enter the actual lighting levels for portions of the building with lighting plans.

ACMs shall allow the user to input a Tailored Lighting Input, lighting control credits and the fraction of light heat rejected to indirectly conditioned spaces for each zone.

The tailored lighting method is intended to accommodate special lighting applications, Complete lighting plans and space plans shall be developed to support the special needs triggering the tailored method. Compliance forms for the tailored method shall be developed and these shall be verified by the plans examiner.

If the tailored lighting method is used, the ACM shall make an entry in the special features section on the compliance forms that the tailored lighting method has been used in compliance and that all necessary tailored lighting forms and worksheets documenting the lighting and its justification shall be provided as part of the compliance documentation and be approved independently.

With the tailored method the use-it-or-lose-it lighting power shall be entered into the ACM separately from the general lighting. No tradeoffs are allowed for the use-it-or-lose-it lighting power.

If a value is input for lighting control credits, the ACM shall output on the compliance documentation that lighting control credits have been used in compliance.

Note: If the standard design would otherwise be modeled with skylights and automatic lighting controls as required by Standards Section 143(c) and Section 131(a), and the user would like to apply an occupancy exception, the user shall select and input the occupancy type(s) of the building from Table N2-2. All occupancies qualifying for the exception are included in the following list: Auditorium, Commercial/Industrial Storage – Refrigerated, Exhibit Display Area and Museum, Theater (Motion Picture), and Theater (Performance).

DOE-2 Command: SPACE

DOE-2 Keyword(s): LIGHTING-SCHEDULE
LIGHTING-W/SQFT
LIGHT-TO-SPACE

Input Type: Required

Tradeoffs: Yes

Modeling Rules for Proposed Design: The proposed design lighting level is restricted based on which of the above two conditions is selected by the user for the building. The proposed design lighting level is determined as follows:

1. *Lighting compliance not performed.* The proposed design lighting level shall be the lighting level listed in Table N2-2 or Table N2-3. ACMs shall report the default lighting energy on PERF-1 and indicate that no lighting compliance was performed. ACMs shall not print any Lighting forms.
2. *Lighting compliance performed.* The proposed design lighting level for each space shall be as follows:
   a) *Nonresidential occupancies*: For each space the proposed design lighting level shall be the actual lighting level of the space as shown in the construction documents and lighting compliance documentation. For each space without specified lighting level, ACMs shall select the default lighting level from Table N2-3 according to the occupancy type of the space.
   b) *High-rise residential and hotel/motel occupancies*: User inputs for lighting (and lighting controls) for the residential units and hotel/motel guest rooms

shall be ignored and the lighting levels determined from Table N2-3 shall be used.

ACMs shall print all applicable lighting forms and report the lighting energy use and the lighting level (Watts/ft^2) for the entire project. ACMs shall report "No Lighting Installed" for nonresidential spaces with no installed lighting. ACMs shall report "Default Residential Lighting" for residential units of high rise residential buildings and hotel/motel guest rooms.

If the modeled Lighting Power Density (LPD) is different than the actual LPD calculated from the fixture schedule for the building, ACMs shall model the larger of the two values for sizing the mechanical systems and for the compliance run. ACMs shall report the larger value on PERF-1. Lighting levels shall be adjusted by any lighting Control Credit Watts, if input by the user.

If daylighting controls are used for daylight zones under skylights greater than 2,500 ft^2 (see Section 131(c)2. of the Standards), then the lighting power for the controlled lighting is reduced by Equation N2-6 for multi-level astronomical time switch controls and Equation N2-7 for automatic multi-level daylighting controls.

Equation N2-6
$$PAF_{ASTRO} = 10 \text{ x Effective Aperture} - \frac{\text{Lighting Power Density}}{10} + 0.2$$

Equation N2-7
$$PAF_{PHOTO} = 2 \text{ x } PAF_{ASTRO}$$

where

Equation N2-8
$$\text{Effective Aperture} = \frac{VLT_{glazing} \times \text{Well Efficiency x Skylight Area x 0.85}}{\text{Daylit Area under Skylights}}$$

$VLT_{glazing}$ = visible transmittance of the glazing system including diffusers, when the etire system is not rated as a whole $VLT_{glazing}$ is the product of the visible transmittance of the components

Well Efficiency = as defined in Standards Section 146(b)4.

Skylight area = the sum of the all of the skylight rough open areas in the zone

Daylit area under skylights = as described in Standards Section 131(c)

Note: In all cases where the photocontrol credit for skylighting is applied, the standard design shall include a multi-level astronomical time switch controls

Modeling Rules for Standard Design (New & Altered Existing):

ACMs shall determine standard design lighting level as follows:

1. *Lighting compliance not performed.* The standard design lighting level shall be the same as the proposed design lighting level.
2. *Lighting compliance performed.*
   a) If no Tailored Lighting Allotment is input and lighting plans will be submitted for the entire building (excluding the residential units of high-rise residential buildings and hotel/motel guest rooms), the standard design lighting level shall be determined from either the whole building or area category method.
   b) If lighting plans will be submitted only for portions of the building, the standard design lighting level in areas without lighting plans shall be the lighting level listed in Table N2-3.
   c) If a tailored lighting method is used, the use-it-or-lose-it power for the proposed design shall be entered separately from the general lighting. The

standard design shall have the same use-it-or-lose-it lighting power as the proposed design.

d) In spaces with skylights that meet the criteria of section 131(c)2, the lighting power density of general lighting shall be reduced by PAF_{ASTRO} as given in Equation N2-6.

e) In spaces that meet the criteria of Standards Section 143(c), the space shall be modeled as having astronomical time switch controls on the general lighting for the greater of the following areas: the actual daylit zone or one half of the area of the space. The lighting power density of general lighting shall be reduced PAF_{ASTRO} as given in Equation N2-6. where Effective aperture shall be taken as 0.01 for spaces with less than 1 W/SF general lighting power density and the effective aperture will be 0.012 for spaces with general lighting power densities greater or equal to 1W/SF.

Modeling Rules for Standard Design (Existing Unchanged):	ACMs shall determine the standard design lighting level of each space the same as it occurs in the existing design.

2.4.3 Schedules

2.4.3.1 Schedule Types

Description:	Schedules are either "Nonresidential," “Retail”, "Hotel Function," or "Residential.”
DOE-2 Command	N/A
DOE-2 Keyword(s)	N/A
Input Type	Required
Tradeoffs	Neutral
Modeling Rules for Proposed Design:	ACMs shall select the schedule type from Table N2-4. If 70 percent or more of the conditioned space in a building served by a central system is one occupancy type, the entire building may be modeled with that occupancy schedule. Otherwise, each occupancy schedule shall be modeled separately with the capacity of the central system allocated to each occupancy schedule according to the portion of the total conditioned floor area served by the central system.
Modeling Rules for Standard Design (All):	The standard design shall use the same schedule type as the proposed design except for the residential units of high-rise residential buildings with or without setback thermostat for which the standard design shall always use the schedule type with setback thermostat (Table N2-7).

2.4.3.2 Weekly Schedules

Description:	The reference method has three different schedules for different days of the week: (1) Weekdays, (2) Saturdays, and (3) Sundays (which includes holidays). Weekly schedules specify: a) the percentage of full load for internal gains; b) thermostat set points for heating and cooling systems; and, c) hours of operation for heating, cooling and ventilation systems.
DOE-2 Command	SPACE
DOE-2 Keyword(s)	SCHEDULE
Input Type	Prescribed
Tradeoffs	Neutral

Modeling Rules for Proposed Design:	Schedules are specified in Table N2-4. For high-rise residential occupancies, ACMs shall require the user to enter whether the proposed design uses setback or non-setback thermostats for heating. ACMs shall use either Table N2-7 or Table N2-8 depending on whether the building uses setback thermostats for heating or uses non-setback thermostats.
Modeling Rules for Standard Design (All):	The standard design shall use the same weekly schedules as the proposed design for nonresidential, retail, and hotel/motel occupancies. For high-rise residential occupancies the standard design shall use the weekly schedules in Table N2-7 assuming setback thermostats for the heating mode.

Table N2-4 – Schedule Types of Occupancies & Sub-Occupancies

Occupancy or Sub-Occupancy Type	Schedule
Atrium	Table 2-4 Nonresidential
Auditorium	Table 2-4: Nonresidential
Auto Repair	Table 2-4: Nonresidential
Bar, Cocktail Lounge and Casino	Table 2-4: Nonresidential
Barber and Beauty Shop	Table 2-4: Nonresidential
Classrooms, Lecture, Training, Vocational Room	Table 2-4: Nonresidential
Civic Meeting Space	Table 2-4: Nonresidential
Commercial and Industrial Storage	Table 2-4: Nonresidential
Convention, Conference, Multipurpose, and Meeting Centers	Table 2-4: Nonresidential
Corridors, Restrooms, Stairs, and Support Areas	Table 2-4: Nonresidential
Dining	Table 2-4: Nonresidential
Electrical, Mechanical Room	Table 2-4: Nonresidential
Exercise Center, Gymnasium	Table 2-4: Nonresidential
Exhibit, Museum	Table 2-4: Nonresidential
Financial Transaction	Table 2-4: Nonresidential
Dry Cleaning (Coin Operated)	Table 2-4: Nonresidential
Dry Cleaning (Full Service Commercial)	Table 2-4: Nonresidential
General Commercial and Industrial Work, High Bay	Table 2-4: Nonresidential
General Commercial and Industrial Work, Low Bay	Table 2-4: Nonresidential
General Commercial and Industrial Work, Precision	Table 2-4: Nonresidential
Grocery Sales	Table 2-4: Nonresidential
High-rise Residential with Setback Thermostat	Table 2-6: Residential / with Setback
High-rise Residential without Setback Thermostat	Table 2-7: Residential / without Setback
Hotel Function Area	Table 2-5: Hotel Function
Hotel/Motel Guest Room with Setback Thermostat	Table 2-6: Residential / with Setback
Hotel/Motel Guest Room without Setback Thermostat	Table 2-7: Residential / without Setback
Housing, Public and Commons Areas, Multi-family with Setback Thermostat	Table 2-6: Residential / with Setback
Housing, Public and Commons Areas, Multi-family without Setback Thermostat	Table 2-7: Residential / without Setback
Housing, Public and Common Areas, Dormitory, Senior Housing with Setback Thermostat	Table 2-6: Residential / with Setback
Housing, Public and Commons Areas, Dormitory, Senior Housing without Setback Thermostat	Table 2-7: Residential / without Setback
Kitchen, Food Preparation	Table 2-4: Nonresidential
Laundry	Table 2-4: Nonresidential
Library, Reading Areas	Table 2-4: Nonresidential
Library, Stacks	Table 2-4: Nonresidential
Lobby, Hotel	Table 2-5: Hotel Function
Lobby, Main Entry	Table 2-4: Nonresidential
Locker/Dressing Room	Table 2-4: Nonresidential
Lounge, Recreation	Table 2-4: Nonresidential
Mall	Table 2-7 Retail
Medical and Clinical Care	Table 2-4: Nonresidential
Office	Table 2-4: Nonresidential
Police Station and Fire Station	Table 2-4: Nonresidential

Occupancy or Sub-Occupancy Type	Schedule
Religious Worship	Table 2-4: Nonresidential
Retail Merchandise Sales, Wholesale Showroom	Table 2-8: Retail
Tenant Lease Space	Table 2-4: Nonresidential
Theater, Motion Picture	Table 2-4: Nonresidential
Theater, Performance	Table 2-4: Nonresidential
Transportation Function	Table 2-4: Nonresidential
Waiting Area	Table 2-4: Nonresidential
All Other	Table 2-4: Nonresidential

Table N2-5 – Nonresidential Occupancy Schedules (Other than Retail)

		Hour																							
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Heating (ºF)	WD	60	60	60	60	60	65	65	70	70	70	70	70	70	70	70	70	70	70	65	60	60	60	60	60
	SAT	60	60	60	60	60	65	65	65	65	65	65	65	65	65	65	65	60	60	60	60	60	60	60	60
	Sun	60	60	60	60	60	65	65	65	65	65	65	65	65	65	65	65	60	60	60	60	60	60	60	60
Cooling (ºF)	WD	77	77	77	77	77	73	73	73	73	73	73	73	73	73	73	73	73	73	77	77	77	77	77	77
	SAT	77	77	77	77	77	73	73	73	73	73	73	73	73	73	73	73	73	73	77	77	77	77	77	77
	Sun	77	77	77	77	77	73	73	73	73	73	73	73	73	73	73	73	73	73	77	77	77	77	77	77
Lights (%)	WD	5	5	5	5	10	20	40	70	80	85	85	85	85	85	85	85	85	80	35	10	10	10	10	10
	SAT	5	5	5	5	5	10	15	25	25	25	25	25	25	25	20	20	20	15	10	10	10	10	10	10
	Sun	5	5	5	5	5	10	10	15	15	15	15	15	15	15	15	15	15	10	10	10	5	5	5	5
Equipment (%)	WD	15	15	15	15	15	20	35	60	70	70	70	70	70	70	70	70	65	45	30	20	20	15	15	15
	SAT	15	15	15	15	15	15	15	20	25	25	25	25	25	25	20	20	20	15	15	15	15	15	15	15
	Sun	15	15	15	15	15	15	15	20	20	20	20	20	20	20	20	20	20	15	15	15	15	15	15	15
Fans (%)	WD	off	off	off	off	off	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	off	off	off	off
	SAT	off	off	off	off	off	on	on	on	on	on	on	on	on	on	on	off	off	off	off	off	off	off	off	off
	Sun	off	off	off	off	off	off	off	off	off	off	off	off	off	off	off	off	off	off	off	off	off	off	off	off
Infiltration (%)	WD	100	100	100	100	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	100	100	100
	SAT	100	100	100	100	100	0	0	0	0	0	0	0	0	0	0	100	100	100	100	100	100	100	100	100
	Sun	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
People (%)	WD	0	0	0	0	5	10	25	65	65	65	65	60	60	65	65	65	65	40	25	10	5	5	5	0
	SAT	0	0	0	0	0	0	5	15	15	15	15	15	15	15	15	15	15	5	5	5	0	0	0	0
	Sun	0	0	0	0	0	0	0	5	5	5	5	5	5	5	5	5	5	5	5	5	0	0	0	0
Hot Water (%)	WD	0	0	0	0	10	10	50	50	50	50	70	90	90	50	50	70	50	50	50	10	10	10	10	0
	SAT	0	0	0	0	0	0	10	20	20	20	20	20	20	20	20	20	20	10	10	10	0	0	0	0
	Sun	0	0	0	0	0	0	0	10	10	10	10	10	10	10	10	10	10	10	10	10	0	0	0	0

Table N2-6 – Hotel Function Occupancy Schedules

		Hour																							
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Heating (ºF)	WD	55	55	55	55	55	55	63	68	70	70	70	70	70	70	70	70	70	70	70	70	70	70	55	55
	SAT	55	55	55	55	55	55	63	68	70	70	70	70	70	70	70	70	70	70	70	70	70	70	55	55
	Sun	55	55	55	55	55	55	63	68	70	70	70	70	70	70	70	70	70	70	70	70	70	70	55	55
Cooling (ºF)	WD	95	95	95	95	95	95	95	95	74	74	74	74	74	74	74	74	74	74	74	74	74	74	74	95
	SAT	95	95	95	95	95	95	95	95	74	74	74	74	74	74	74	74	74	74	74	74	74	74	74	95
	Sun	95	95	95	95	95	95	95	95	74	74	74	74	74	74	74	74	74	74	74	74	74	74	74	95
Lights (%)	WD	5	5	5	5	5	5	5	5	25	50	90	90	90	90	90	90	75	50	50	50	50	10	5	5
	SAT	5	5	5	5	5	5	5	5	25	50	90	90	90	90	90	90	75	50	50	50	50	10	5	5
	Sun	5	5	5	5	5	5	5	5	25	50	90	90	90	90	90	90	75	50	50	50	50	10	5	5
Equipment (%)	WD	5	5	5	5	5	5	5	5	50	50	50	50	30	50	50	50	30	10	30	30	30	10	5	5
	SAT	5	5	5	5	5	5	5	5	50	50	50	50	30	50	50	50	30	10	30	30	30	10	5	5
	Sun	5	5	5	5	5	5	5	5	50	50	50	50	30	50	50	50	30	10	30	30	30	10	5	5
Fans (%)	WD	off	off	off	off	off	off	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	off
	SAT	off	off	off	off	off	off	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	off
	Sun	off	off	off	off	off	off	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	off
Infiltration (%)	WD	100	100	100	100	100	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100
	SAT	100	100	100	100	100	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100
	Sun	100	100	100	100	100	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100
People (%)	WD	0	0	0	0	0	0	0	5	35	90	90	90	25	90	90	90	50	25	50	50	50	10	0	0
	SAT	0	0	0	0	0	0	0	5	35	90	90	90	25	90	90	90	50	25	50	50	50	10	0	0
	Sun	0	0	0	0	0	0	0	5	35	90	90	90	25	90	90	90	50	25	50	50	50	10	0	0
Hot Water (%)	WD	0	0	0	0	0	0	10	40	40	60	60	60	90	60	60	60	60	40	50	50	50	10	0	0
	SAT	0	0	0	0	0	0	10	40	40	60	60	60	90	60	60	60	60	40	50	50	50	10	0	0
	Sun	0	0	0	0	0	0	10	40	40	60	60	60	90	60	60	60	60	40	50	50	50	10	0	0

Table N2-7 – Residential Occupancy Schedules (Including Hotel/Motel Guest Rooms) With Setback Thermostat For Heating

		Hour																							
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Heating (ºF)	WD	60	60	60	60	60	60	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	60	60
	SAT	60	60	60	60	60	60	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	60	60
	Sun	60	60	60	60	60	60	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	60	60
Cooling (ºF)	WD	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78
	SAT	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78
	Sun	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78
Lights (%)	WD	10	10	10	10	10	30	45	45	45	45	30	30	30	30	30	30	30	30	60	80	90	80	60	30
	SAT	10	10	10	10	10	30	45	45	45	45	30	30	30	30	30	30	30	30	60	80	90	80	60	30
	Sun	10	10	10	10	10	30	45	45	45	45	30	30	30	30	30	30	30	30	60	80	90	80	60	30
Equipment (%)	WD	10	10	10	10	10	30	45	45	45	45	30	30	30	30	30	30	30	30	60	80	90	80	60	30
	SAT	10	10	10	10	10	30	45	45	45	45	30	30	30	30	30	30	30	30	60	80	90	80	60	30
	Sun	10	10	10	10	10	30	45	45	45	45	30	30	30	30	30	30	30	30	60	80	90	80	60	30
Fans (%)	WD	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on
	SAT	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on
	Sun	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on
Infiltration (%)	WD	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	SAT	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	Sun	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
People (%)	WD	90	90	90	90	90	90	70	40	40	20	20	20	20	20	20	30	50	50	50	70	70	80	90	90
	SAT	90	90	90	90	90	90	70	40	40	20	20	20	20	20	20	30	50	50	50	70	70	80	90	90
	Sun	90	90	90	90	90	90	70	40	40	20	20	20	20	20	20	30	50	50	50	70	70	80	90	90
Hot Water (%)	WD	0	0	0	5	5	5	80	70	50	40	25	25	25	25	50	60	70	70	40	25	20	20	5	5
	SAT	0	0	0	5	5	5	80	70	50	40	25	25	25	25	50	60	70	70	40	25	20	20	5	5
	Sun	0	0	0	5	5	5	80	70	50	40	25	25	25	25	50	60	70	70	40	25	20	20	5	5

Table N2-8 – Residential Occupancy Schedules (Including Hotel/Motel Guest Rooms) Without Setback Thermostat

		Hour																							
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Heating (ºF)	WD	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68
	SAT	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68
	Sun	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68
Cooling (ºF)	WD	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78
	SAT	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78
	Sun	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78	78
Lights (%)	WD	10	10	10	10	10	30	45	45	45	45	30	30	30	30	30	30	30	30	60	80	90	80	60	30
	SAT	10	10	10	10	10	30	45	45	45	45	30	30	30	30	30	30	30	30	60	80	90	80	60	30
	Sun	10	10	10	10	10	30	45	45	45	45	30	30	30	30	30	30	30	30	60	80	90	80	60	30
Equipment (%)	WD	10	10	10	10	10	30	45	45	45	45	30	30	30	30	30	30	30	30	60	80	90	80	60	30
	SAT	10	10	10	10	10	30	45	45	45	45	30	30	30	30	30	30	30	30	60	80	90	80	60	30
	Sun	10	10	10	10	10	30	45	45	45	45	30	30	30	30	30	30	30	30	60	80	90	80	60	30
Fans (%)	WD	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on
	SAT	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on
	Sun	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on
Infiltration (%)	WD	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	SAT	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	Sun	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
People (%)	WD	90	90	90	90	90	90	70	40	40	20	20	20	20	20	20	30	50	50	50	70	70	80	90	90
	SAT	90	90	90	90	90	90	70	40	40	20	20	20	20	20	20	30	50	50	50	70	70	80	90	90
	Sun	90	90	90	90	90	90	70	40	40	20	20	20	20	20	20	30	50	50	50	70	70	80	90	90
Hot Water (%)	WD	0	0	0	5	5	5	80	70	50	40	25	25	25	25	50	60	70	70	40	25	20	20	5	5
	SAT	0	0	0	5	5	5	80	70	50	40	25	25	25	25	50	60	70	70	40	25	20	20	5	5
	Sun	0	0	0	5	5	5	80	70	50	40	25	25	25	25	50	60	70	70	40	25	20	20	5	5

Table N2-9 – Retail Occupancy Schedules

		Hour																							
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Heating (ºF)	WD	60	60	60	60	60	63	65	68	70	70	70	70	70	70	70	70	70	70	70	65	65	65	65	60
	SAT	60	60	60	60	60	63	65	68	70	70	70	70	70	70	70	70	70	70	70	65	65	65	65	60
	Sun	60	60	60	60	60	63	65	68	70	70	70	70	70	70	70	70	70	70	70	65	65	65	65	60
Cooling (ºF)	WD	80	80	80	80	80	74	74	74	74	74	74	74	74	74	74	74	74	74	74	74	74	74	80	80
	SAT	80	80	80	80	80	74	74	74	74	74	74	74	74	74	74	74	74	74	74	74	74	74	80	80
	Sun	80	80	80	80	80	74	74	74	74	74	74	74	74	74	74	74	74	74	74	74	74	74	80	80
Lights (%)	WD	20	20	20	20	20	30	40	65	90	90	90	90	90	90	90	90	90	90	90	80	65	50	35	25
	SAT	20	20	20	20	20	30	40	65	90	90	90	90	90	90	90	90	90	90	90	80	65	50	35	25
	Sun	20	20	20	20	20	30	40	65	90	90	90	90	90	90	90	90	90	90	90	80	65	50	35	25
Equipment (%)	WD	20	20	20	20	20	25	30	45	60	75	75	75	70	75	75	75	75	75	65	55	45	35	25	20
	SAT	20	20	20	20	20	25	30	45	60	75	75	75	70	75	75	75	75	75	65	55	45	35	25	20
	Sun	20	20	20	20	20	25	30	45	60	75	75	75	70	75	75	75	75	75	65	55	45	35	25	20
Fans (%)	WD	off	off	off	off	off	off	On	on	on	on	on	on	on	on	on	on	on	on	on	on	on	off	off	off
	SAT	off	off	off	off	off	off	On	on	on	on	on	on	on	on	on	on	on	on	on	on	on	off	off	off
	Sun	off	off	off	Off	off	off	On	on	on	on	on	on	on	on	on	on	on	on	on	on	on	off	off	off
Infiltration (%)	WD	100	100	100	100	100	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	100	100
	SAT	100	100	100	100	100	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	100	100
	Sun	100	100	100	100	100	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	100	100
People (%)	WD	05	05	05	05	05	05	15	25	40	55	75	75	75	75	75	75	75	75	65	50	35	20	10	5
	SAT	05	05	05	05	05	05	15	25	40	55	75	75	75	75	75	75	75	75	65	50	35	20	10	5
	Sun	05	05	05	05	05	05	15	25	40	55	75	75	75	75	75	75	75	75	65	50	35	20	10	5
Hot Water (%)	WD	0	0	0	0	0	0	10	10	50	50	70	90	90	50	50	70	50	50	50	10	10	0	0	0
	SAT	0	0	0	0	0	0	10	10	50	50	70	90	90	50	50	70	50	50	50	10	10	0	0	0
	Sun	0	0	0	0	0	0	10	10	50	50	70	90	90	50	50	70	50	50	50	10	10	0	0	0

2.4.3.3 Holiday Schedules

Description

The reference method has Weekdays, Saturdays and Sundays schedules which includes holidays. The 1991 calendar year is a fixed input, with January 1st being a Tuesday and no leap year. The following holidays observed in the simulation:

New Year's Day	Tuesday, January 1
Martin Luther King's Birthday	Monday, January 21
Washington's Birthday	Monday, February 18
Memorial Day	Monday, May 27
Independence Day	Thursday, July 4
Columbus Day	Monday, October 14
Veteran's Day	Monday, November 11
Thanksgiving Day	Thursday, November 28
Christmas Day	Wednesday, December 25

DOE-2 Command

DOE-2 Keyword(s) SCHEDULE

Input Type Prescribed

Tradeoffs Neutral

Modeling Rules for Proposed Design: The proposed design shall use the Sunday occupancy schedule for the above holidays.

Modeling Rules for Standard Design (All): The standard design shall use the same schedule as the proposed design.

2.5 HVAC Systems and Plants

ACMs shall have the capability to accept input for and model various types of HVAC systems. In central systems, these modeling features affect the loads seen by the plant. A key factor related to equipment type is the energy source (electricity, natural gas, or propane). ACMs shall correctly apply the TDV multiplier from Joint Appendix III for each fuel source, building type and climate zone.

Standard design requirements are labeled as applicable to one of the following options:

- Existing unchanged
- Altered existing
- New
- All

with the default condition for these four specified conditions being “All.” An ACM without the optional capability of analyzing additions or alterations shall classify and report all HVAC components as “All.”

2.5.1 Thermal Zoning

Description: A space or collection of spaces within a building having sufficiently similar space-conditioning requirements that those conditions could be maintained with a single controlling device.

ACMs shall accept input for and be capable of modeling a minimum of fifty (50) thermal zones, each with its own control. ACMs shall also be capable of reporting the number of control points at the building level. When the number of control points is not greater than twenty (20) the ACM shall have one HVAC zone per control point. An ACM may use zone multipliers for identical zones.

When the number of zones exceeds twenty, then (and only then) thermal zones may be combined subject to a variety of rules and restrictions. See Chapter 4 for details on restrictions on combining thermal zones and requirements for zoning buildings for which no HVAC permit is sought.

DOE-2 Command	ZONE
DOE-2 Keyword(s)	ZONE-TYPE
Input Type	Prescribed
Tradeoffs	Neutral
Modeling Rules for Proposed Design:	The reference method models thermal zones as input by the user, according to the plans and specifications for the building. If thermal zones can not be determined from the building plans, thermal zones shall be established from guidelines in the ACM User's Manual and Help System (see Chapter 4).
Modeling Rules for Standard Design (All):	ACMs shall model the thermal zones of the standard design in the same manner as they are modeled in the proposed design.

2.5.2 Heating & Cooling Equipment

2.5.2.1 Primary Systems

The ACM shall be able to model the following primary systems:

- *Hydronic*. Primary system cooling/heating coil served by a central hydronic system.
- *Electric*. Primary system heating using electric resistance.
- *Fossil fuel furnace*. Primary system heating by a fossil fuel fired furnace.
- *Heat pump*. Primary system heating provided by direct expansion refrigerant coils served by a heat pump.
- *DX (Direct Expansion)*. Primary system cooling provided by direct expansion refrigerant coils served by a heat pump or other compression system.

2.5.2.2 Cooling Equipment

The ACM shall account for variations in cooling equipment efficiency and capacity. ACMs will be compared to and tested against a reference method that also accounts for variations in efficiency and capacity as a function of part-load ratio and heat transfer fluid (e.g., chilled water, condenser water, outside air for air-cooled systems) temperatures. The ACM user shall be able to explicitly enter equipment type and capacity and standard efficiency ratings (such as SEER and/or EER for packaged equipment).

In certain cases the Standards allow cooling equipment to be installed below the mandatory minimum efficiency ratings listed in the Standards for new currently manufactured equipment, e.g. existing equipment moved to a new location in the building. If an ACM allows efficiencies to be entered (optional entry and capability) lower than those indicated in the mandatory features for newly manufactured equipment, then those entries shall also be indicated in the exceptional conditions checklist on the PERF-1 and be justified in writing.

ACMs shall model two fundamental types of cooling equipment:

1. Water chillers. Cooling equipment that chills water to be supplied to building coils.
2. *Direct expansion (DX) compressors.* Cooling systems that directly cool supply air without first cooling a heat transfer medium such as water. See descriptions above for other definitions.

The reference method models part-load performance for at least two different types of water chillers and all ACMs shall allow the user to select either of these two chiller types:

1. *Centrifugal.* Compression refrigeration system using rotary centrifugal compressor.
2. *Reciprocating.* Compression refrigeration system using reciprocating positive displacement compressor.

2.5.2.3 Heating Equipment

The ACM shall account for variations in heating equipment performance according to efficiency and as a function of load. The user shall be able to explicitly enter equipment type and capacity and rated efficiency (such as AFUE, Steady State Thermal Efficiency or HSPF).

In certain cases the Standards allow heating equipment to be installed below the mandatory minimum efficiency ratings listed in the Standards for new currently manufactured equipment, e.g. existing equipment moved to a new location in the building. If an ACM allows efficiencies to be entered (optional entry and capability) lower than those indicated in the mandatory features for newly manufactured equipment, those entries shall also be indicated in the exceptional conditions checklist on the PERF-1 and be justified in writing.

ACMs shall model three fundamental types of heating equipment:

1. *Furnaces.* The following forced air furnaces shall be provided:
   - *Electric.* Electric resistance elements used as the heating source.
   - *Fossil Fuel*. Natural gas or liquid propane is used as the heating source.
2. *Boilers*. The following capabilities shall be provided for boilers:
   - *Electric*. Boiler uses electric resistance heating.
   - *Fossil Fuel*. Boiler is natural gas or oil fired.
   - *Natural draft*. Fossil fired boiler uses natural draft (atmospheric) venting.
   - *Forced/induced draft*. Fossil fired boiler uses fan forced or induced draft venting.
     With this option, the ACM shall account for fan energy.
   - *Hot water*. Boiler produces hot water.
3. *Heat Pumps*. Supply air is heated through direct expansion process utilizing electricity as the fuel type and outside air as the heat source.

2.5.2.4 Standard Design Systems

Description: The reference method will assign one of five Standard Design System types for all proposed HVAC systems in order to establish an energy budget for the standard building. This system is generated and modeled for all buildings, even if no mechanical heating or cooling is included in the building permit.

ACMs shall require the user to input the following for each system:

1. **Building Type** - low-rise nonresidential, high-rise nonresidential, residential and hotel/motel guest room
2. **System Type** - single zone, multiple zone
3. **Heating Source** - fossil fuel, electricity
4. **Cooling Source** - hydronic, other (for high-rise residential and hotel/motel guest room, only)

All ACMs shall accept input for and be able to model the following system types for both the standard and proposed design:

- <u>**System 1**</u>: Packaged Single Zone (PSZ), Gas furnace and electric air conditioner.

- **System 2**: Packaged Single Zone (PHP), Electric heat pump and air conditioner.
- **System 3**: Packaged Variable Air Volume (PVAV), Central gas boiler with hydronic reheat and electric air conditioner.
- **System 4**: Built-up Variable Air Volume (VAV), Central gas boiler with hydronic reheat and central electric chiller with hydronic air conditioning.
- **System 5**: Four-pipe fan coil (FPFC), Central gas boiler and electric chiller serving individual units with hydronic heating and cooling coils.

DOE-2 Command	SYSTEM
DOE-2 Keyword(s)	SYSTEM-TYPE
Input Type	Prescribed
Tradeoffs	N/A
Modeling Rules for Proposed Design:	The proposed system shall be input as it is shown in the construction documents for the building. ACMs shall receive enough input about the proposed system to: 1) generate the applicable standard design system; 2) apply all required efficiency descriptors to both the standard and proposed designs; and, 3) model the energy use of the proposed design accurately.
Modeling Rules for Standard Design (New):	The standard design system selection is shown in Table N2-10. The reference method chooses the standard HVAC system only from the five minimum systems listed above. The reference method will select its standard system according to Table N2-10, for the standard design system, regardless of the system type chosen for the proposed design. For example, a hydronic heating system served by a gas-fired boiler to supply hot water to the loop for a low-rise nonresidential building is considered a single zone (fan) system with fossil fuel for a heating source, and would be compared to System #1 - a Packaged Single Zone Gas/Electric System. Likewise a gas-fired absorption cooling system with a gas-fired furnace serving a single zone would be compared to System #1 also. Tables N2-11 through N2-14 describe the five standard design system types.
Modeling Rules for Standard Design (Existing Unchanged & Altered Existing):	The standard design shall model the existing system with its rated efficiency. If the entered efficiency is lower than those indicated in the mandatory features for newly manufactured equipment, then those entries shall also be indicated in the exceptional conditions checklist on the PERF-1 and be noted as existing system.

Table N2-10 – Standard Design System Selection Flowchart

Building Type	*System Type*	*Proposed Design Heating Source*	*System*
Low-Rise Nonresidential	Single Zone	Fossil	System 1 – Packaged Single Zone, Gas/Electric
		Electric	System 2 – Packaged Single Zone, Heat Pump
	Multiple Zone	Any	System 3 – Packaged VAV, Gas Boiler with Reheat
High Rise Nonresidential	Single Zone	Any	System 5 – Four Pipe Fan Coil System with Central Plant
	Multiple Zone	Any	System 4 – Central VAV, Gas Boiler with Reheat
Residential & Hotel/Motel Guest Room	Hydronic	Any	System 5 – Four Pipe Fan Coil System with Central Plant
	Other	Fossil	System 1 (No economizer) – Packaged Single Zone, Gas/Electric
		Electric	System 2 (No economizer) – Packaged Single Zone, Heat Pump

Table N2-11 – System #1 and System #2 Descriptions

System Description:	Packaged Single Zone with Gas Furnace/Electric Air Conditioning (#1) or Heat Pump (#2)
Supply Fan Power:	See Section 2.5.3.5
Supply Fan Control:	Constant volume
Min Supply Temp:	$50 \leq T \leq 60$ DEFAULT: 55
Cooling System:	Direct expansion (DX)
Cooling Efficiency:	Minimum SEER or EER based on equipment type and output capacity of proposed unit(s). Adjusted EER is calculated to account for supply fan energy.
Maximum Supply Temp:	$85 \leq T \leq 110$ DEFAULT: 100
Heating System:	Gas furnace (#1) or heat pump (#2)
Heating Efficiency:	Minimum AFUE, Thermal Efficiency, COP or HSPF based on equipment type and output capacity of proposed unit(s).
Economizer:	Integrated dry-bulb economizer, when mechanical cooling output capacity of the proposed design as modeled in the compliance run by the ACM is over 75,000 Btu/hr and fan system volumetric capacity of the proposed design as modeled in the compliance run by the ACM is over 2500 cfm
Ducts:	For ducts installed in unconditioned buffer spaces or outdoors as specified in Section 144(k) of the Standards, the duct system efficiency shall be as described in Section 2.5.3.18.

Table N2-12 System #3 Description

System Description:	Packaged VAV with Boiler and Reheat
Supply Fan Power:	See Section 2.5.3.5
Supply Fan Control:	Individual VAV supply fan with less than 10 horsepower: VAV - forward curved fan with discharge damper Individual VAV supply fan greater than or equal to ten horsepower: VAV - variable speed drive
Return Fan Control:	Same as supply fan
Minimum Supply Temp:	$50 \leq T \leq 60$ DEFAULT: 55
Cooling System:	Direct expansion (DX)
Cooling Efficiency:	Minimum efficiency based on average proposed output capacity of equipment unit(s)
Maximum Supply Temp:	$90 \leq T \leq 110$ DEFAULT: 105
Heating System:	Gas boiler
Hot Water Pumping System	Variable flow (2-way valves) riding the pump curve
Heating Efficiency:	Minimum efficiency based on average proposed output capacity of equipment unit(s)
Economizer:	Integrated dry-bulb economizer, when mechanical cooling output capacity of the proposed design as modeled in the compliance run by the ACM is over 75,000 Btu/hr and fan system volumetric capacity of the proposed design as modeled in the compliance run by the ACM is over 2500 cfm

Table N2-13 System #4 Description

System Description:	Chilled Water VAV With Reheat
Supply Fan Power:	See Section 2.5.3.5
Supply Fan Control:	Individual VAV supply fan with less than 10 horsepower:: VAV - forward curved fan with discharge damper Individual VAV supply fan with greater than or equal to 10 horsepower: VAV - variable speed drive
Return Fan Control:	Same as supply fan
Minimum Supply Temp:	$50 \leq T \leq 60$ DEFAULT: 55
Cooling System:	Chilled water
Chilled Water Pumping System	Variable flow (2-way valves) with a VSD on the pump if three or more fan coils or air handlers. Constant volume flow with water temperature reset control if less than three fan coils or air handlers.
Cooling Efficiency:	Minimum efficiency based on average proposed output capacity of equipment unit(s)
Maximum Supply Temp:	$90 \leq T \leq 110$ DEFAULT: 105
Heating System:	Gas boiler
Hot Water Pumping System	Variable flow (2-way valves) riding the pump curve if three or more fan coils or air handlers. Constant volume flow with water temperature reset control if less than three fan coils or air handlers.
Heating Efficiency:	Minimum efficiency based on average proposed output capacity of equipment unit(s)
Economizer:	Integrated dry-bulb economizer, when mechanical cooling output capacity of the proposed design as modeled in the compliance run by the ACM is over 75,000 Btu/hr and fan system volumetric capacity of the proposed design as modeled in the compliance run by the ACM is over 2500 cfm

Table N2-14 – System #5 Description

System Description:	Four-Pipe Fan Coil With Central Plant
Supply Fan Power:	See Section 2.5.3.5
Minimum Supply Temp:	$50 \leq T \leq 60$ DEFAULT: 55
Cooling System:	Chilled water
Chilled Water Pumping System	Variable flow (2-way valves) with a VSD on the pump if three or more fan coils. Constant volume flow with water temperature reset control if less than three fan coils.
Cooling Efficiency:	Minimum efficiency based on the proposed output capacity of specific equipment unit(s)
Maximum Supply Temp:	$90 \leq T \leq 110$ DEFAULT: 100
Heating System:	Gas boiler
Hot Water Pumping System	Variable flow (2-way valves) riding the pump curve if three or more fan coils. Constant volume flow with water temperature reset control if less than three fan coils.
Heating Efficiency:	Minimum efficiency based on the proposed output capacity of specific equipment unit(s)
Economizer:	Integrated dry-bulb economizer, when mechanical cooling output capacity of the proposed design as modeled in the compliance run by the ACM is over 75,000 Btu/hr and fan system volumetric capacity of the proposed design as modeled in the compliance run by the ACM is over 2500 cfm

2.5.2.5 Combining Like Systems

Description:	When several similar thermal zones with similar heating/cooling units are combined (see Section 4.3.6.19 for conditions that lead to thermal zones being similar) or similar heating/cooling units with similar controls serve a thermal zone, the ACM may combine the system heating and cooling capacities, supply air flow rates, and fan power for the zone. The ACM shall require the user to input the number of such systems. The ACM shall receive a value for this input for fan systems, packaged heating or cooling equipment, chillers and boilers. If equipment or systems are grouped for modeling purposes, the efficiency of the combined system shall be the weighted average of efficiencies of all systems based on the size of each unit. If the user inputs a value greater than 1 for the number of heating/cooling units, the ACM shall print a warning on the Performance Summary form, PERF-1, indicating that systems of similar type have been modeled as one system and that a prescriptive Mechanical Equipment Summary form, MECH-3, shall be attached documenting each individual system. Refer to Chapter 4, Section 4.3.6.19 for discussion of allowed like system types.
DOE-2 Command	N/A
DOE-2 Keyword(s)	N/A
Input Type	Default
Tradeoffs	N/A
Modeling Rules for	The reference program may model one heating/cooling unit with heating and cooling

Proposed Design:	capacities, supply air flow rate, and fan power equal to the total capacities, air flow rates, and fan power of the combined systems. The efficiency shall be equal to the capacity weighted average efficiency for the systems being combined.
Default:	One system
Modeling Rules for Standard Design (All):	The reference program shall model the standard design using Standard Design System types and the applicable capacities, supply air flow rate, fan power, and the minimum efficiency requirements.

2.5.2.6 Equipment Performance of Air Conditioners and Heat Pumps without SEER Ratings

Scope

Air conditioners or heat pumps with a capacity greater than 65,000 Btu/h.

Description

The hourly performance of air-to-air air conditioners and heat pumps varies with the outdoor temperature, the loading conditions, the wetbulb temperature of the air returning to the indoor coil, and other factors. The reference method takes account of these factors through a set of equipment performance curves that modify the efficiency or the capacity of the equipment with changes in part-load ratio, outside dry-bulb temperature and wet-bulb temperature of the return air (across the indoor coil).

The four reference method performance curves specified here include.

COOL-CAP-FT	Cooling capacity as a function of outdoor dry bulb and return wet bulb air temperatures.
COOL-EIR-FT	Cooling efficiency as a function of outdoor dry bulb and return wet bulb temperatures.
HEAT-EIR-FT	Heating efficiency as a function of outdoor dry bulb and return wet bulb temperatures.
HEAT-CAP-FT	Heating capacity as a function of outdoor dry bulb temperature and the return wet bulb temperature. This curve adjusts the capacity of the heat pump as the ODB changes. This is an important curve for heat pumps as an electric resistance element comes on to provide heat when the heat pump has inadequate capacity.
MAX-HP-SUPP-T	This parameter is the outside drybulb temperature below which the heat pump supplemental heating is allowed to operate. This parameter shall be set to 70 ^{o}F.

Other equipment performance curves, such as COOL-EIR-PLR, which are not specified in this manual shall be the default curves defined in DOE-2.1E Reference Manual Supplement, Lawrence Berkeley Laboratory Document #LBL-8706, Rev. 5.

COOL-CAP-FT

The COOL-CAP-FT curve in the reference method adjusts the capacity of the cooling equipment in response to the outdoor drybulb temperature and the wetbulb temperature of the air returning to the indoor coil.

Equation N2-9 $$\text{COOL-CAP-FT} = a + b * EWB + c * EWB^2 + d * ODB + e * ODB^2 + f * EWB * ODB$$

where:

COOL-CAP-FT =	Normalized cooling capacity of the equipment for the EWB and ODB specified.
EWB =	Wet bulb temperature of air entering the indoor coil.
ODB =	Outdoor dry bulb temperature.
a, b, c, d, e, f =	Regression constants and coefficients.

COOL-EIR-FT

The COOL-EIR-FT curve adjusts the efficiency of the cooling equipment in response to the outdoor drybulb temperature and the wetbulb temperature of the air returning to the indoor coil.

Equation N2-10 $$\text{COOL-EIR-FT} = A + b * EWB + c * EWB^2 + d * ODB + e * ODB^2 + f * EWB * ODB$$

where:

T24-COOL-EIR-FT = Normalized cooling energy input ratio for Title 24 standards

EWB = Entering wet bulb temperature

ODB = Outdoor dry bulb temperature

a, b, c, d, e, f = Regression constants and coefficients

HEAT-EIR-FT

This curve in the reference method adjusts the efficiency of the heating equipment in response to the outdoor drybulb temperature.

Equation N2-11 $$\text{HEAT-EIR-FT} = a + b * ODB + c * ODB^2 + d * ODB^3$$

where:

T24-HEAT-EIR-FT = Normalized heating energy input ratio for Title 24 standards

ODB = Outdoor dry bulb temperature

a, b, c, d = Regression constants and coefficients

HEAT-CAP-FT

This curve adjusts the capacity of the heat pump in response to the outdoor drybulb temperature. This curve adjusts the capacity of the heat pump as the ODB changes. This is an important curve for heat pumps as an electric resistance element comes on to provide heat when the heat pump has inadequate capacity.

Equation N2-12 $$\text{HEAT-CAP-FT} = a + b * ODB + c * ODB^2 + d * ODB^3$$

where

HEAT-CAP-FT = Normalized heating capacity

ODB = Outdoor dry bulb temperature

a, b, c, d = Regression constants and coefficients

Default

The default equipment performance curves coefficients are specified in Table N2-15.

Table N2-15 – Default Coefficients for COOL-CAP-FT, COOL-EIR-FT, HEAT-CAP-FT and HEAT-EIR-FT Equations

Coefficient	COOL-CAP-FT	COOL-EIR-FT	HEAT-CAP-FT	HEAT-EIR-FT
a	0.053815799	-0.4354605	0.253761	1.563358292
b	0.02044874	0.0499555	0.010435	0.013068685
c	-1.45568E-05	-0.0004849	0.000186	-0.001047325
d	-0.000891816	-0.011332	-1.50E-06	1.08867E-05
e	-1.22969E-05	0.00013441		
f	-2.61616E-05	0.00002016		

Tradeoffs

Yes for COOL-EIR-FT, COOL-CAP-FT, HEAT-CAP-FT, and HEAT-EIR-FT. Neutral for the part load equipment performance curves.

Input Type	Required.
Proposed Design Modeling Assumptions	For equipment larger than 135,000 Btu/h, the user may enter data on equipment performance as described below. In this case, the ACM shall use the algorithms described below to determine the temperature dependent performance curves for the proposed design equipment. If the user chooses not to enter data on temperature dependent performance, then the defaults shall be used. For equipment with a capacity less than or equal to 135,000 Btu/h, but larger than 65,000 Btu/h, the user may not enter data on the temperature dependent equipment performance. However, the ACM vendor may work with manufacturers to collection such data and build this data into the ACM. The user may either select equipment for which the ACM vendor has collected or use the defaults.
Standard Design Modeling Assumptions	The standard design equipment uses the default performance curves coefficients specified in Table N2-15.
Algorithms	The reference method shall be able to calculate custom regression coefficients with market data and user-entered data as well as use default coefficients. The default coefficients listed below in Table N2-15 are derived from market data. The method allows the user to enter data for a wet bulb of 67 degrees, and generates data points at other wet bulb temperatures by scaling the user-entered data at a given dry bulb temperature by the wet bulb adjustment predicted by the default performance curve in Table N2-15. The reference program uses a computer program to calculate custom regression constants and coefficients for the performance curves according to the following rules. The input data shall have a minimum of 4 full load points for each performance curve analyzed, including the 95 odb/67ewb ARI point. The user cannot directly modify the curve coefficients.
User Inputs	If non-default values are used for equipment performance, users shall input the gross cooling capacity (GCC) and rated power (PWR) at an entering coil wetbulb temperature of 67 ºF. A minimum of four values shall be entered and one of the values shall be for the ARI rated condition of 95 ºF ODB. The data should be for a nominal fan flow of 400 cfm per ton of rated capacity. The minimum of four data points should include one drybulb temperatures at 85 ºF or lower and one at 115 ºF or higher. The data to be entered are the values in the the shaded areas of Table N2-16. Other blanks in Table N2-16 shall be calculated as described below.

Table N2-16 – Data Input Requirements for Equipment Performance Curves

A	B	C	D	E	F	G	H
Point	EWB	ODB	CAP	PWR	EIR	$NCAP_{ARI}$	$NCAP_{ARI}$
1	67						
2	67						
3	67						
4	67						
5	67						
6	62						
7	62						
8	62						
9	62	Not Used					
10	62						
11	72						
12	72						
13	72						
14	72						
15	72						

Calculating EIR (Column F)

The EIR in column F of Table N2-16 shall be calculated as follows from data in columns D and E as shown in the equation below.

Equation N2-13
$$EIR = \frac{PWR}{CAP / 3413}$$

Note that the supply fan shall not be included in the PWR term in Equation N2-14. If data from the manufacturers includes the supply fan power, an adjustment may be made using the procedures in Section 2.5.2.7 of this manual. Neither should the PWR term include the condenser fan, however, the calculated EIR will be sufficiently accurate if the condenser fan is included in the calculation. The condenser fan power is not significant for two reasons. First, the compressor power dominates the power requirements of the system, and second, the EIR values are later normalized, i.e. if each EIR value is calculated in a consistent manner, the ratio will not be significantly affected.

Calculating Normalized Cooling Capacities (Column G)

Inputs to the reference method require a normalized cooling capacity value, which is the ratio of the cooling capacity at a particular combination of ODB and EWB to the capacity at the ARI conditions of 95 ºF ODB and 67 ºF EBT. The normalized capacity is calculated from Equation N2-14. For the ARI rated condition of 95 ºF ODB, this ratio will be one. This calculation is made only for the 67 EWB data points, for which data is entered.

Equation N2-14
$$NCAP_{EWB,ODB} = \frac{CAP_{EWB,ODB}}{CAP_{67,95}}$$

Calculating Normalized Energy Input Ratio (Column H)

Inputs to the reference method require a normalized EIR value, which is the ratio of the EIR at a particular combination of ODB and EWB to the EIR at the ARI conditions of 95 ºF ODB and 67 ºF EBT. The normalized EIR is calculated from Equation N2-15. For the ARI rated condition of 95 ºF ODB, this ratio will be one. This calculation is made only for the 67 EWB data points, for which data is entered.

Equation N2-15

$$NEIR_{EWB,ODB} = \frac{EIR_{EWB,ODB}}{EIR_{67,95}}$$

Creating Data Points for 62 ºF and 72 ºF WBT

Generating the equipment performance curve requires data points for EWB of 62 ºF and 72 ºF. These data points are not entered by the user, but rather are scaled from the default equipment performance curve as shown in the equations below.

Equation N2-16

$$EIRRatio_{EWB,ODB} = EIRRatio_{67,ODB} \times \frac{DefEIRRatio_{EWB,ODB}}{DefEIRRatio_{67,ODB}}$$

Equation N2-17

$$CAPRatio_{EWB,ODB} = CAPRatio_{67,ODB} \times \frac{DefCAPRatio_{EWB,ODB}}{DefCAPRatio_{67,ODB}}$$

Error Checking

Cooling capacity entered for a given wet bulb temperature shall be monotonically decreasing as dry bulb temperature increases. In addition the energy input ratio (EIR) resulting from the entered data shall be monotonically increasing as dry bulb temperature increases. If either or these conditions are violated, the program shall generate an ERROR message indicating that entered capacity information is in error and will not be used in the simulation.

An ERROR message shall also be generated if the range of outside dry bulb temperatures entered is higher than 85 ºF or lower than 115 ºF or if a data point is not entered for 95 ºF outside dry bulb temperature.

The DOE-2 Curve-Fit Function

Once the data in Table N2-16 entered and/or calculated according to the procedures above, the data is then entered in the DOE-2 reference method using the curve fit function. Typical inputs are as described below.

```
COOL-CAP-FT-User  =  CURVE-FIT
TYPE              =  BI-QUADRATIC
DATA              =  ( 67,75, NCAP67,75,
                       67,85, NCAP67,85,
                       67,95,1.0,                  $ARI Rated conditions
                       67,105, NCAP67,105,
                       67,115, NCAP67,115,
                       62,75, NCAP62,75,
                       62,85, NCAP62,85,
                       62,95, NCAP62,95,
                       62,105, NCAP62,105,
                       62,115, NCAP62,115,
                       72,75, NCAP72,75,
                       72,85, NCAP72,85,
                       72,95, NCAP72,95,
                       72,105, NCAP72,105,
                       72,115, NCAP72,115 )

COOL-EIR-FT-User  =  CURVE-FIT
TYPE              =  BI-QUADRATIC
DATA              =  ( 67,75, NCAP67,75,
                       67,85, NCAP67,85,
                       67,95,1.0,                  $ARI Rated conditions
                       67,105, NCAP67,105,
                       67,115, NCAP67,115,
                       62,75, NCAP62,75,
```

62,85, $NCAP_{62,85}$,
62,95, $NCAP_{62,95}$,
62,105, $NCAP_{62,105}$,
62,115, $NCAP_{62,115}$,
72,75, $NCAP_{72,75}$,
72,85, $NCAP_{72,85}$,
72,95, $NCAP_{72,95}$,
72,105, $NCAP_{72,105}$,
72,115, $NCAP_{72,115}$)

2.5.2.7 Equipment Performance of Air Conditioners with SEER Ratings and Heat Pumps with SEER and HSPF Ratings

Scope	Air conditioners and heat pumps with a capacity of 65,000 Btu/h or less and which are rated by the National Appliance and Energy Conservation Act (NAECA).
Description	The efficiency of NAECA air conditioners depends on the temperature of the outside air and other factors. As the temperature increases, the air conditioner becomes less efficient and it has reduced capacity. Likewise, with electric heat pumps in the heating mode, as the outdoor temperature drops, the efficiency declines and so does the capacity. This section of the ACM manual describes the methods and algorithms used by the reference method to account for these factors. See the previous section on non-NAECA air conditioners and heat pumps for more general information on equipment performance curves used by the reference method.
Input	ACMs shall require the user to enter the SEER (seasonal energy efficiency ratio). The user may also optionally enter the EER (energy efficiency ratio). ACMs shall require the user to enter the HSPF (heating seasonal performance factor). The user may also optionally enter the COP (coefficient of performance) at 47 F and the ACM may allow the user to enter COP 17 F. From these data the reference method determines equipment performance curves.
Proposed Design Modeling Assumptions	The proposed design shall use the SEER and EER and HSPF of the equipment shown on the plans and included in the construction specifications. As an alternative to HSPF, the ACM shall allow the user to enter a COP at 47 F and may allow a user to enter a COP at 17 F. When a user enters HSPF but does not enter COP 47 F and COP 17 F, the ACM shall calculate the COP 47 F and COP 17 F as described for the Standard Design.
Standard Design Modeling Assumptions	The standard design shall use performance curves based on the SEER of the equipment required by the Standards. The default EER, as defined below shall be used. The standard design heat pump shall have an HSPF as required by section 111. The COP at 47 F shall be determined as below. The efficiency at other outdoor temperatures shall be based on the default DOE-2 HEAT-EIR-FT curve. For single package units and split systems: COP47 = HSPF * 0 28 + 1.13 The standard design shall determine the COP at other outside temperatures from the DOE 2 default curves.
Tradeoffs	Yes for cooling and heat pump efficiency adjustments for ODB. Neutral for other equipment performance curves.
COOL-EIR-FT	This curve explains how the efficiency of the cooling equipment varies with the ODB and the EWB. This curve is derived from entered or default values of SEER and EER, using the procedures below. The curve is defined as a bi-quadratic with the coefficients in the following BDL.

COOL-EIR- FT =	CURVE-FIT
TYPE =	BI-QUADRATIC
DATA =	(67, 95, 1.0, $ARI Test Conditions
	57, 82, $NEIR_{57,82}$
	57, 95, $NEIR_{57,95}$,
	57,110,$NEIR_{57,110}$,
	67, 82, $NEIR_{67, 82}$,
	67,110, $NEIR_{67,110}$,
	77, 82, $NEIR_{77, 82}$,
	77, 95, $NEIR_{77,95}$,
	77,110, $NEIR_{77, 110}$)
OUTPUT-MIN =	$NEIR_{67, 82}$

$NEIR_{WBT,ODB}$ represents the normalized energy input ratio (EIR) for various entering wetbulb (EWB) and outside drybulb (ODB) temperatures. The value represents the EIR at the specified EWB and ODB conditions to the EIR at standard ARI conditions of 67 ºF wetbulb and 95 ºF drybulb. The COOL-EIR-FT curve is normalized at ARI conditions of 67 ºF entering wetbulb and 95 ºF outside drybulb so $NEIR_{67,95}$ is one or unity, by definition. For other EWB and ODB conditions, values of NEIR are calculated with Equation N2-18.

Equation N2-18
$$NEIR_{EWB,ODB} = \frac{EIR_{EWB,ODB}}{EIR_{67,95}}$$

The energy input ratio (EIR) is the unitless ratio of energy input to cooling capacity. EIR includes the compressor and condenser fan, but not the supply fan. If the energy efficiency ratio EERnf (EER excluding the fan energy) is known for a given set of EWB and ODB conditions, the EIR for these same conditions is given by Equation N2-19 below. The units of EER are (Btu/h)/W.

Equation N2-19
$$EIR_{EWB,ODB} = \frac{3.413}{EERnf_{EWB,ODB}}$$

If the EER (including fan energy) is known for a given set of EWB and ODB conditions, then the EERnf (no fan) can be calculated from Equation N2-20 below.

Equation N2-20
$$\begin{aligned} EERnf_{EWB,ODB} &= 1.0452 \times EER_{EWB,ODB} \\ &+ 0.0115 \times EER_{EWB,ODB}{}^2 \\ &+ 0.000251 \times EER_{EWB,ODB}{}^3 \times F_{TXV} \times F_{AIR} \end{aligned}$$

The EER for different EWB and ODB conditions. These are given by the following equations.

Equation N2-21
$$EER_{67,82} = SEER$$

Equation N2-22
$$\begin{aligned} EER_{67,95} &= \text{From Manufacturers Data} \quad [\text{when available}] \\ &= 10 - (11.5 - SEER) \times 0.83 \quad [\text{default for SEER} < 11.5] \\ &= 10 \quad [\text{default for SEER} \geq 11.5] \end{aligned}$$

Equation N2-23 $$EER_{67,110} = EER_{67,95} - 1.8$$

Equation N2-24 $$EER_{57,ODB} = 0.877 \times EER_{67,ODB}$$

Equation N2-25 $$EER_{77,ODB} = 1.11 \times EER_{67,ODB}$$

F_{TXV} Refrigerant charge factor, default = 0.9. For systems with a verified TXV or verified refrigerant charge, the factor shall be 0.96.

F_{AIR} Airflow adjustment factor. Default cooling air flow shall be assumed in calculations for any system in which the air flow has not been tested, certified and verified. For ACM energy calculations the F_{air} multiplier shall be set to 0.925 for systems with default cooling air flow. For systems with air flow verified, F_{air} shall be 1.00.

EERnf Energy Efficiency Ratio at ARI conditions without distribution fan consumption, but adjusted for refrigerant charge and airflow.

COOL-CAP-FT This performance curve explains how the capacity of the cooling equipment varies as a function of the ODB and the EWB. The default curve defined by the curve coefficients in Table N2-15 shall be used for both the standard design and proposed design.

COOL-EIR-FPLR This performance curve explains how the efficiency of the cooling equipment varies with the part load ratio. Since the effects of part load are captured in the COOL-EIR-FT curve, this curve is disabled. The following input is used in the reference method for both the proposed design and the standard design.

T24NAECADEF-COOL-EIR-FPLR = CURVE-FIT
TYPE = LINEAR
COEF = (0,1)

HEAT-EIR-FT For heat pumps, the reference method uses performance curves based on the ratio of the COPs and CAPACITIES at 47 ºF and at 17 ºF (COP_{47}, COP_{17}, CAP_{47}, CAP_{17}) and creates new performance curves, using the following points for ODB and the COPs and CAPACITIES at these temperatures. For single-zone systems with ducts installed in unconditioned buffer spaces or outdoors as specified in Section 144(k) of the Standards for which the verified sealed duct option has been elected, the HP-EIR-FT shall be divided by the seasonal distribution efficiencies as determined in Section 2.5.3.18.

HP-EIR-FT = CURVE-FIT
TYPE = CUBIC
DATA = (67,0.856)
= (57,0.919)
= (47,1.000)
= ($17,COP_{47}/COP_{17}$)
= ($7,1.266 \times COP_{47}/COP_{17}$)
= (-13, 3.428)

HEAT-CAP-FT This curve adjusts the capacity of the heat pump as the ODB changes. This is an important curve for heat pumps as an electric resistance element comes on to provide heat when the heat pump has inadequate capacity.

HP-CAP-FT = CURVE-FIT
TYPE = CUBIC
DATA = (67,1.337)
= (57,1.175)

= (47,1.000)
= (17,CAP_{17}/CAP_{47})
= (7,0.702×CAP_{17}/CAP_{47})
= (-13, 0.153)

MAX-HP-SUPP-T This parameter is the outside drybulb temperature below which the heat pump supplemental heating is allowed to operate. This parameter shall be set to 70 ^{o}F.

2.5.2.8 Efficiency of Cooling Equipment Included in Built-up Systems

Description ACMs shall require the user to input: (1) the type of central cooling plant equipment proposed (e.g. open centrifugal, open reciprocating, water chiller, direct expansion, etc.); (2) the number of central cooling units and the capacity of each unit; (3) the efficiency of each central cooling unit; and (4) the type of refrigerant to be used in each central cooling unit. ACMs shall not accept user-defined performance curves for any equipment except for electric chillers.

DOE-2 Command

DOE-2 Keyword(s) COOLING-EIR

Input Type Default

Tradeoffs Yes

Modeling Rules for Proposed Design: The ACM shall require the user to input efficiency descriptors at ARI test conditions for all equipment documented in plans and specifications for the building.

Default: Minimum efficiency as specified in the Appliance Efficiency Regulations or Tables 112-A through 112-E of the Building Energy Efficiency Standards.

Modeling Rules for Standard Design (New): Based on the capacity and type of chiller(s) the reference method assigns the EER of each unit of the standard design according to the applicable requirements of the Appliance Efficiency Standards or the Standards.

Modeling Rules for Standard Design (Existing Unchanged & Altered Existing): ACMs shall use the EER and the ARI fan power of the existing system.

2.5.2.9 Heating Efficiency of Heat Pumps with Ratings Other than HSPF

Scope This section applies to heat pumps that have a cooling capacity larger than 65,000 Btu/h for which there is neither a SEER or HSPF rating.

Description ACMs shall require the user to input the COP for all packaged heat pump equipment with fans that are not covered by DOE appliance standards.

ACMs shall also require the user to input the net heating capacity, $HCAP_a$, at ARI conditions for all equipment.

The reference method calculates the electrical heating input ratio, HIR, according to the following equation:

$$HIR = \frac{[HCAP_a/(COP \times 3.413)] - ARIFanPower}{(HCAP_a/3.413) - ARIFanPower}$$

For single-zone systems with ducts installed in unconditioned buffer spaces or outdoors as specified in Section 144(k) of the Standards, the HEATING-HIR shall be divided by the seasonal distribution efficiencies as determined in Section 2.5.2.18.

DOE-2 Command

DOE-2 Keyword(s)	HEATING-HIR
Input Type	Default
Tradeoffs	Yes
Modeling Rules for Proposed Design:	The ACM shall require the user to input efficiency descriptors as they occur in the construction documents.
Default:	Minimum COP as specified in either the Appliance Efficiency Regulations or Table 112-B of the Building Energy Efficiency Standards.
Modeling Rules for Standard Design (New):	For the reference method, the HIR of each unit in the standard design is determined according to the applicable requirements of the Appliance Efficiency Standards or the Standards.
Modeling Rules for Standard Design (Existing Unchanged & Altered Existing):	ACMs shall determine the HIR of each existing system using the COP and the ARI fan power of the existing system.

2.5.2.10 Heating Efficiency of Fan Type Central Furnaces with AFUE Ratings

Description

ACMs shall require the user to input: (1) the AFUE; (2) the heating capacity; and (3) the system configuration for all fan type central furnaces that are rated with AFUE in the Appliance Efficiency Standards.

The reference method calculates an equivalent heating input ratio, HIR, according to the following:

a) For single package units:

Equation N2-26 $$HIR = (0.005163 \times AFUE + 0.4033)^{-1}$$

b) For split systems with AFUEs not greater than 83.5:

Equation N2-27 $$HIR = (0.002907 \times AFUE + 0.5787)^{-1}$$

c) For split systems with AFUEs greater than 83.5:

Equation N2-28 $$HIR = (0.011116 \times AFUE - 0.098185)^{-1}$$

For single-zone systems with ducts installed in spaces between insulated ceilings and roofs or building exteriors for which the verified sealed duct option has been elected, the HEATING-HIR shall be divided by the seasonal efficiencies as determined in Section 2.5.2.35.

DOE-2 Command	
DOE-2 Keyword(s)	HEATING-HIR
Input Type	Default
Tradeoffs	Yes
Modeling Rules for Proposed Design:	ACMs shall require the user to input the AFUE of each DOE covered central furnace.
Default:	Minimum AFUE as specified in the Appliance Efficiency Regulations
Modeling Rules for	The reference method assigns an HIR of 1.24 to all standard design heating

Standard Design (New):	systems when a fan-type central furnace is the proposed heating system.
Modeling Rules for Standard Design (Existing Unchanged & Altered Existing):	ACMs shall determine the HIR of each existing system using the AFUE of the existing system.

2.5.2.11 Heating Efficiency Fan Type Central Furnaces with Ratings Other than AFUE

Description:	The ACM shall require the user to input the steady state efficiency, or the HIR, of each furnace for each furnace's rated capacity. For single-zone systems with ducts installed in unconditioned buffer spaces or outdoors as specified in Section 144(k) of the Standards, the HEATING-HIR shall be divided by the seasonal distribution efficiencies as determined in Section 2.5.3.18.
DOE-2 Command	
DOE-2 Keyword(s)	HEATING-HIR
Input Type	Default
Tradeoffs	Yes
Modeling Rules for Proposed Design:	The ACM shall require the user to input efficiency descriptors as they occur in the construction documents.
Default:	Minimum Thermal Efficiency or Combustion Efficiency as specified in either the Appliance Efficiency Regulations or Table 112-F of the Building Energy Efficiency Standards.
Modeling Rules for Standard Design (New):	The standard design shall assign the HIR of each unit according to the applicable requirements of the Standards.
Modeling Rules for Standard Design (Existing Unchanged & Altered Existing):	ACMs shall determine the HIR of each existing system using the AFUE of the existing system.

2.5.2.12 Efficiency of Boilers

Description:

ACMs shall require the user to input: (1) the type of central boiler proposed (steam or water, forced or induced draft, etc); (2) the number of central boilers and the capacity of each unit; (3) the heating input ratio of each boiler; and (4) the type of primary fuel used in each boiler. ACMs shall use the same boiler part-load curve for the proposed and standard designs. The reference method uses the DOE 2.1E default part-load curves for boilers. ACMs are not allowed to accept user-defined part-load curves for boilers.

ACMs shall calculate an equivalent heating input ratio, HIR, according to the following:

a) $75 \leq \text{AFUE} < 80$

Equation N2-29 $$\text{HIR} = (0.1 \times \text{AFUE} + 72.5)^{-1} \times 100$$

b) $80 \leq \text{AFUE} < 100$

c) Boilers with Thermal Efficiency (Et). HIR for boilers is determined by dividing the thermal efficiency Et into 1.

Equation N2-30 $$HIR = (0.875 \times AFUE + 10.5)^{-1} \times 100$$

DOE-2 Input Type	
DOE-2 Tradeoffs	BOILER-HIR
	Default
	Yes
Modeling Rules for Proposed Design:	The reference method converts, to an HIR, the user input AFUE as documented in the plans and specifications for the building.
Default:	Minimum AFUE as specified in the Appliance Efficiency Regulations
Modeling Rules for Standard Design (New):	The standard design shall assign the HIR of each unit according to the applicable requirements of the Standards.
Modeling Rules for Standard Design (Existing Unchanged & Altered Existing):	ACMs shall determine the HIR of each existing system using the AFUE of the existing system.

2.5.2.13 Air-Cooled Condensers

The reference method shall model air-cooled condensers as integral to the cooling plant equipment specified. Direct expansion compressors with air-cooled condensers shall include the EIR of the condenser with the EIR of the compressor. Air-cooled water chillers shall include the EIR of the condenser with the EIR of the chiller.

2.5.2.14 Calculating EIR for Packaged Equipment

The EIR shall be calculated according to Equation N2-31, except when supply/return fan heat is excluded by the manufacturer when calculating the EER. In that case, the EER shall be calculated according to the following equation:

Equation N2-31 $$EIR_a = \frac{(CAP_a / EER)}{(CAP_a / 3.413) + ARIFanPower}$$

Refer to Section 2.5.3.14 (Chiller Characteristics) for modeling rules for air-cooled chillers.

2.5.2.15 Electric Motor Efficiency

Description: The full-load efficiency of the electric motor established in accordance with NEMA Standard MG1-1998 (Rev. 2). The standard design shall use the minimum nominal full-load efficiency shown in Table N2-17. For systems with multiple motors, the reference program combines the mechanical efficiencies as the horsepower weighted average, as follows:

Equation N2-32 $$MEFF_{combine} = \frac{\sum_{i=1}^{n} (HP_i \times MEFF_i)}{\sum_{i=1}^{n} HP_i}$$

	where
	$MEFF_{combine}$ = Combined mechanical efficiency
	$MEFF_i$ = Mechanical efficiency of the i^{th} motor
	HP_i = Horsepower of the i^{th} motor
	n = Total number of motors being combined
DOE-2 Keyword(s)	SUPPLY-MECH-EFF RETURN-EFF
Input Type	Default
Tradeoffs	Yes
Modeling Rules for Proposed Design:	The ACM shall require the user to input the full-load efficiency for all electric motors used for HVAC and service hot water that are documented in the plans and specifications for the building as established in accordance with NEMA Standard MG1-1998 (Rev. 2).
Default:	Standard motor efficiency from Table N2-17.
Modeling Rules for Standard Design (New):	The standard design shall use the appropriate minimum efficiency values from Table N2-17.
Modeling Rules for Standard Design (Existing Unchanged & Altered Existing):	The standard design shall use the full-load efficiency of existing electric motors as established in accordance with NEMA Standard MG1-1998 (Rev. 2)N. If the efficiency of the existing motor is not available the standard design shall use the default motor efficiency from Table N2-17.

Table N2-17 – Minimum Nominal Efficiency for Electric Motors (%)

Motor Horsepower	Open Motors				Enclosed Motors			
	2 poles 3600 rpm	4 poles 1800 rpm	6 poles 1200 rpm	8 poles 900 rpm	2 poles 3600 rpm	4 poles 1800 rpm	6 poles 1200 rpm	8 poles 900 rpm
1	-	82.5	80.0	74.0	75.5	82.5	80.0	74.0
1.5	82.5	84.0	84.0	75.5	82.5	84.0	85.5	77.0
2	84.0	84.0	85.5	85.5	84.0	84.0	86.5	82.5
3	84.0	86.5	86.5	86.5	85.5	87.5	87.5	84.0
5	85.5	87.5	87.5	87.5	87.5	87.5	87.5	85.5
7.5	87.5	88.5	88.5	88.5	88.5	89.5	89.5	85.5
10	88.5	89.5	90.2	89.5	89.5	89.5	89.5	88.5
15	89.5	91.0	90.2	89.5	90.2	91.0	90.2	88.5
20	90.2	91.0	91.0	90.2	90.2	91.0	90.2	89.5
25	91.0	91.7	91.7	90.2	91.0	92.4	91.7	89.5
30	91.0	92.4	92.4	91.0	91.0	92.4	91.7	91.0
40	91.7	93.0	93.0	91.0	91.7	93.0	93.0	91.0
50	92.4	93.0	93.0	91.7	92.4	93.0	93.0	91.7
60	93.0	93.6	93.6	92.4	93.0	93.6	93.6	91.7
75	93.0	94.1	93.6	93.6	93.0	94.1	93.6	93.0
100	93.0	94.1	94.1	93.6	93.6	94.5	94.1	93.0
125	93.6	94.5	94.1	93.6	94.5	94.5	94.1	93.6
150	93.6	95.0	94.5	93.6	94.5	95.0	95.0	93.6
200	94.5	95.0	94.5	93.6	95.0	95.0	95.0	94.1
250	94.5	95.0	95.4	94.5	95.4	95.0	95.0	94.5
300	95.0	95.4	95.4	-	95.4	95.4	95.0	-
350	95.0	95.4	95.4	-	95.4	95.4	95.0	-
400	95.4	95.4	-	-	95.4	95.4	-	-
450	95.8	95.8	-	-	95.4	95.4	-	-
500	95.8	95.8	-	-	95.4	95.8	-	-

2.5.3 Air Distribution Systems

2.5.3.1 ARI Fan Power

The *ARI Fan Power* is required to calculate the electrical input ratios (EIR) described above. The reference method determines the *ARI Fan Power* for systems 1, 2 and 3 by assuming that the *ARI Fan Power* is fixed at **365 watts per 1000 cfm with supply air flow rate fixed at 400 cfm per 12,000 Btu/h cooling capacity**.

2.5.3.2 Fan System Configuration

Description:	ACMs shall model the configuration of fan systems as described below.
DOE-2 Command	
DOE-2 Keyword(s)	FAN-PLACEMENT MOTOR-PLACEMENT
Input Type	Prescribed
Tradeoffs	N/A
Modeling Rules for	• Same specifications as the standard design.

Proposed Design:

Modeling Rules for Standard Design (All):

The proposed design system shall assume the following:

- For systems 1 through 4, all supply fans shall be "draw-through" type, positioned downstream from all heating and cooling sources.
- For system 5, the supply fan shall be a "blow-through " type, positioned upstream from heating and cooling sources.
- ACMs may combine return fans with the supply fan if and only if the controls are of the same type. For example, ACMs may combine fans if they all have variable speed drive control or if they all are constant volume fans.
- Return fans are those that are required to operate at design conditions to draw air from conditioned zones and can either return that air back to the source (the intake of the supply fan system) or exhaust it to the outdoors. Exhaust fans that are manually switched such as bathroom fans shall not be included in the fan model.

All fan motor heat shall be rejected to the supply air stream

2.5.3.3 Fan System Operation

Description:

Operating schedule of fan systems are in the standard schedules. Fan systems shall operate continuously (turned on) during scheduled operation hours for all occupancy types **except** for the residential units of high-rise residential buildings and hotel/motel guest rooms. In these occupancies, the user may model the fan operation either as *continuous* or *intermittent*. For continuous fan operation, the fan operates during scheduled operation hours regardless of whether heating or cooling is needed.

DOE-2 Command

DOE-2 Keyword(s)

FAN-SCHEDULE
INDOOR-FAN-MODE
NIGHT-CYCLE-CONTROL

Input Type

Default

Tradeoffs

Neutral

Modeling Rules for Proposed Design:

ACMs shall model the fan operation as *continuous* for all occupancy types during scheduled operation hours except for the residential units of high-rise residential buildings and hotel/motel guest rooms. For these occupancies, ACMs shall accept input for the type of fan operation (*continuous* or *intermittent)*. For intermittent fan operation, the fan operates only when heating or cooling is needed. The DOE-2 Keyword for intermittent fan operation is:

INDOOR-FAN-MODE = INTERMITTENT

The DOE-2 Keyword for continuous fan operation is:

INDOOR-FAN-MODE = CONTINUOUS

Default:

INDOOR-FAN-MODE = CONTINUOUS

Modeling Rules for Standard Design (All):

Standard design fan system operation shall be identical to the proposed design except when the user specifies electric resistance heating without a fan system for residential units of high-rise residential buildings and hotel/motel guest rooms. In such cases the standard design fan operation shall be *intermittent*.

2.5.3.4 Fan Volume Control

Description:	ACMs shall be capable of modeling different types of supply and return fans for standard design systems 3 and 4. Modeling shall account for the part-load-ratio of the fan, which is the ratio of supply air rate at any given flow to the supply air rate at design flow (maximum flow). All ACMs that explicitly model variable air volume HVAC systems shall require the user to input the type of fan volume control for each supply/return fan combination in the proposed design. Minimum required fan volume controls and associated part-load-curves are given below in the form of DOE 2.1 curve-fit instructions.
DOE-2 Curve-Fit for Constant Volume	Fan supplies a constant volume of air at constant power draw whenever it is in operation. This fan control does not have a part-load-curve.
DOE-2 Curve-Fit for Forward Curved Centrifugal Fan with Discharge Dampers	Variable volume fan with static pressure control dampers at the fan outlet or with no direct static pressure control.

```
FC-FAN-W/DAMPERS = CURVE-FIT
            TYPE = QUADRATIC
      OUTPUT-MIN = 0.22
            DATA = (.0,1.0)
                   (0.9,0.88)
                   (0.8,0.75)
                   (0.7,0.66)
                   (0.6,0.55)
                   (0.5,0.47)
                   (0.4,0.40)
                   (0.3,0.33)
                   (0.2,0.27)
```

DOE-2 Curve Fit Forward Curved Centrifugal Fan with Inlet Vanes

Variable volume fan with static pressure flow controlled by vanes at the fan inlet.

```
FC-FAN-W/VANES = CURVE-FIT
          TYPE = QUADRATIC
    OUTPUT-MIN = 0.22
          DATA = (1.0,1.0)
                 (0.9,0.78)
                 (0.8,0.60)
                 (0.7,0.48)
                 (0.6,0.38)
                 (0.5,0.29)
                 (0.4,0.24)
                 (0.3,0.23)
                 (0.2,0.22)
```

DOE-2 Curve Fit for Air foil Centrifugal Fan with Inlet Vanes

Fan is controlled by variable inlet vanes.

```
AF-FAN-W/VANES = CURVE-FIT
```

TYPE	=	QUADRATIC
OUTPUT-MIN	=	0.48
DATA	=	(1.0,1.0)
	=	(0.9,0.83)
	=	(0.8,0.71)
	=	(0.7,0.66)
	=	(0.6,0.60)
	=	(0.5,0.55)
	=	(0.4,0.52)
	=	(0.3,0.48)

DOE-2 Curve Fit for Variable Speed Drive: Variable volume fan of any type with static pressure control by an AC frequency invertor varying fan speed.

ANY-FAN-W/VSD	=	CURVE-FIT
TYPE	=	QUADRATIC
OUTPUT-MIN	=	0.10
DATA	=	(1.0,1.0)
	=	(0.9,0.78)
	=	(0.8,0.57)
	=	(0.7,0.40)
	=	(0.6,0.29)
	=	(0.5,0.20)
	=	(0.4,0.15)
	=	(0.3,0.11)
	=	(0.2,0.10)

DOE-2 Command	SYSTEM
DOE-2 Keyword(s)	FAN-CONTROL
Input Type	Prescribed
Tradeoffs	N/A
Modeling Rules for Proposed Design:	The ACM shall model the same fan volume control for proposed systems as documented in the plans and specifications for the building. The user may not enter part-load curves for fans or other HVAC equipment.
Modeling Rules for Standard Design (New):	ACMs shall assume a *variable speed drive* for fan volume control for each proposed fan in standard design systems 3 and 4 when the fan motor is greater than 10 horsepower. For systems 1, 2, and 5, ACMs shall assume the same fan volume control as the proposed design.
Modeling Rules for Standard Design (Existing Unchanged & Altered Existing):	ACMs shall use the existing fan volume control for the standard design.

2.5.3.5 Fan Power

Description

ACMs shall model all HVAC fans in the system that are required to operate at design conditions. These include supply fans, exhaust fans (that operate during peak), return fans, relief fans, and fan power terminal units (either series or parallel). The reference program models the fan system power demand using the fan power index (FPI). Fan power index is defined as the power consumption of the fan system divided by the volume of air moved (W/cfm).

For each fan that operates during normal HVAC operation (except for the fan-coil system serving the residential unit of a high-rise residential building or a hotel/motel guest room), ACMs shall require the user to input: 1) the design BHP; 2) the design drive motor efficiency; and, 3) the design motor efficiency, all at peak design air flow rates. Exhaust fans that are manually controlled (such as bathroom fans) may not operate at design conditions and therefore shall **not** be included in the fan system power demand calculations.

The reference method calculates the FPI for each fan system according to the following equation:

Equation N2-33

$$FPI = \frac{746}{CFMs}\left[\frac{BHPs}{\eta ds \times \eta ms} + \frac{BHPr}{\eta dr \times \eta mr} + \frac{BHPo}{\eta do \times \eta mo}\right]$$

where:

FPI	=	fan power index, [W/cfm]
CFM_S	=	peak supply air flow rate, [ft³/min]
BHP_S	=	brake horsepower of supply fan at CFM_S [hp]
BHP_r	=	brake horsepower of return fan at CFM_S [hp]
BHP_o	=	brake horsepower of other fans at CFM_S [hp]
h_{ms}	=	supply motor efficiency [unitless]
h_{mr}	=	return motor efficiency [unitless]
h_{mo}	=	other motor efficiency [unitless]
h_{ds}	=	supply drive efficiency [unitless]
h_{dr}	=	return drive efficiency [unitless]
h_{mo}	=	other drive efficiency [unitless]

If the user does not input the design brake horsepower (BHP) and the peak supply air flow rate (cfm) for forced air systems, the ACM shall assume that no mechanical compliance will be performed and shall model the default mechanical system according to the rules in Section 2.5.3.9 (modeling default heating and cooling systems).

DOE Keywords:

SUPPLY-kW
SUPPLY-DELTA-T
RETURN-kW
RETURN-DELTA-T

Input Type: Required

Tradeoffs: Yes

Modeling Rules for Proposed Design: All ACMs shall model proposed system fan power as documented in the plans and specifications for the building. The proposed design shall use the fan motor efficiency established in accordance with NEMA Standards MG1-1998 (Rev. 2). System fan power shall include all fans that operate during peak cooling conditions, including fans in terminal units. For ECM motors in series fan powered terminal units with systems 3 or 4, the modeled power shall be 50% of the maximum rated power. Standard motors in series fan powered terminal units shall be modeled at 100% of the maximum rated power. Qualifying ECM motors shall have a motor efficiency of at least 70% when rated with NEMA Standard MG-1-1998 (Rev. 2).

Modeling Rules for Standard Design (New): The reference method determines the standard design fan power as follows:

a) For systems 1, 2, and 5 with proposed FPI $\leq$ 0.80: The standard design FPI shall be the same as the proposed design.

b) For systems 1, 2 and 5 and proposed FPI > 0.80: The standard design FPI shall be 0.80.

c) For systems 3 and 4 and proposed FPI $\leq$ 1.25: The standard design FPI shall be the same as the proposed design.

d) For systems 3 and 4 and proposed FPI > 1.25: The standard design FPI shall be 1.25.

The reference method shall use the appropriate minimum nominal full-load motor efficiency from Table N2-17.

Modeling Rules for Standard Design (Existing Unchanged & Altered Existing): All ACMs shall model the existing system fan power according to the specifications of the existing system. The reference method shall use the full-load nominal efficiency of the existing motor as established in accordance with NEMA Standard MG1. If the efficiency of the existing motor is not available, ACMs shall use the appropriate minimum nominal full-load motor efficiency from Table N2-17.

2.5.3.6 Process Fan Power

The portion of the total fan power exclusively used for air treatment or filtering systems. For each fan system used for air treatment or filtering, ACMs shall adjust the fan power index according to the following equation:

Equation N2-34 $$\text{Adjusted Fan Power Index (FPI)} = \text{Total FPI} \times (1 - (SP_a - 1) / SP_f)$$

where:

SP_a = Air pressure drop across air treatment or filtering system, and

SP_f = Total pressure drop across the fan system

Fans whose fan power exclusively serve as process fans shall not be modeled for simulation.

2.5.3.7 Air Economizers

Description: The reference method is capable of simulating an economizer that: (1) modulates outside air and return rates to supply up to 100% of design supply air quantity as outside air; and, (2) modulates to a fixed position at which the minimum ventilation air is supplied when the economizer is not in operation.

The reference method will simulate at least two types of economizers and all ACMs shall receive input for these two types of economizers:

1. *Integrated*. The economizer is capable of providing partial cooling, even when additional mechanical cooling is required to meet the remainder of the cooling

load. The economizer is shut off when outside air temperature or enthalpy is greater than a fixed setpoint.

2. *Nonintegrated/fixed set point.* This strategy allows only the economizer to operate below a fixed outside air temperature set point. Above that set point, only the compressor can provide cooling.

DOE-2 Keyword(s)	ECONO-LIMIT ECONO-LOCKOUT ECONO-LOW-LIMIT
Input Type	Default
Tradeoffs	Yes
Modeling Rules for Proposed Design:	The ACM shall allow the user to input either an *integrated* or *non-integrated* economizer as described above as it occurs in the construction documents. The ACM shall require the user to input the ODB set point.
Default:	No Economizer
Modeling Rules for Standard Design (New):	The standard design shall assume an *integrated* air economizer, available for cooling any time ODB < T_{limit}, on systems 1, 2, 3 and 4 (See Standard Design Systems Types) when mechanical cooling output capacity of the proposed design as modeled in the compliance run by the ACM is over 75,000 Btu/hr and fan system volumetric capacity of the proposed design as modeled in the compliance run by the ACM is over 2500 cfm. T_{limit} shall be set to 75°F for climate zones 1, 2, 3, 5, 11, 13, 14, 15 & 16. T_{limit} shall be set to 70°F for climate zones 4, 6, 7, 8, 9, 10 & 12. The ACM shall not assume economizers on any system serving high-rise residential and hotel/motel guest room occupancies.
Modeling Rules for Standard Design (Existing Unchanged & Altered Existing):	All ACMs shall model existing economizers as they occur in the existing building.

2.5.3.8 Sizing Requirements

ACMs shall use outdoor weather design conditions for the building location from ACM Joint Appendix II for calculating design heating and cooling loads. In rural locations the user may enter a building location that is shown to have the most similar weather rather than the closest city with the explicit approval of the local enforcement agency. The same city shall appear for all reports of building location and design weather data. The indoor design air temperature is based on the occupancy type using Table N2-5, Table N2-6, Table N2-7, and Table N2-8.

ACMs shall perform design heating and cooling load calculations for each zone of the standard design and proposed design. The design load methodology shall be consistent with the ASHRAE Handbook, , Fundamentals Volume, or with another method approved by the Executive Director.

The reference method uses the following assumptions for design loads:

- *Fixed Design Assumptions by Occupancy.* User values as listed in Table N2-2 and Table N2-3. Different occupancy schedules are used by the reference method to determine design loads. For cooling loads, lights, equipment/receptacles, and people are at 100% of full load while the building is occupied. For heating loads, these internal gains are 0% of full load at all hours of the day. The HVAC equipment operational hours and thermostat settings schedules shall be based on the selected occupancy type using the occupancy schedules shown in Table N2-5, Table N2-6, Table N2-7, and Table N2-8
- *Ventilation and Process Loads*. See applicable sections on ventilation and process loads.
- *Outdoor Design Temperatures, Summer Daily Temperature Swing and Latitude.* The ACM shall use the Heating Winter Median of Extremes temperature, and the 0.5 percent Cooling Dry-Bulb, and Mean

Coincident Wet-Bulb temperatures from ACM Joint Appendix II; or the user shall be able to enter these values directly into the ACM. The ACM shall use the daily temperature range for the design cooling day from the hourly weather file for the city selected.

ACMs shall calculate, for both the standard design and proposed design, heating and cooling loads and appropriate capacities for supply fans, cooling and heating equipment, hydronic pumps and heat rejection equipment. ACMs must be capable of calculating loads and capacities for the five standard design systems. All assumptions for heating and cooling equipment and fan system sizing are documented below.

Cooling Loads

Description

The reference method calculates cooling loads for each fan system using the following assumptions:

- Peak cooling design day profiles from ACM Joint Appendix II for the city in which the building will be built. These profiles shall be developed using a method similar to the design day method of the reference computer program.
- All window interior and user-operated shading devices are ignored.
- Internal gains from occupants and receptacle loads are fixed at 100% of the values listed in Table N2-2 or Table N2-3while the building is occupied.

Indoor dry-bulb temperatures are specified according to

- Table N2-5, Table N2-6, Table N2-7, and Table N2-8; however, the ACM shall be able to calculate the indoor wet-bulb temperature using the occupancy information and the cooling coil characteristics.
- Outdoor design temperatures equal to those listed in the 0.5 Percent Cooling Design Dry Bulb and Mean Coincident Wet-Bulb columns of ACM Joint Appendix II. For cooling tower design, temperatures listed in the Summer Design Wet-Bulb 0.5% columns shall be used.

Modeling Rules for Proposed Design:

The reference method calculates the proposed design cooling load using the same assumptions used by the mechanical system designer, including all proposed lighting, ventilation and process load at a constant 100% of the levels documented in the plans and specifications for the building. That is internal loads are all at 100% of full load for the duration of the cooling load calculation.

Modeling Rules for Standard Design (All):

- The reference method shall use the same loads as the proposed design.

Heating Loads

Description

The reference method calculates heating loads for each fan system using the following assumptions:

- Indoor design temperatures according to Table N2-2 or Table N2-3.
- No direct solar heat gains.
- All internal gains -- occupants, receptacle loads, other loads (such as pickup load) and lighting levels shall be assumed to be 0% of user input, default and fixed values.

Indoor design temperatures according to

- Table N2-5, Table N2-6, Table N2-7, or Table N2-8.
- Outdoor design temperatures equal to those in the Winter Median of Extremes

column in ACM Joint Appendix II.

Sizing Procedure for Systems 1, 3, 4, and 5

Modeling Rules for Proposed Design:

1. Calculate proposed fan air flow requirements, cfm_{pc}, based on the design supply air temperature input by the user. The calculated proposed fan air flow requirement is the larger of the heating and cooling air flow requirements, but no lower than 0.4 cfm/ft^2 overall.

NOTE: In the text that follows regarding the "design procedure" or "sizing procedure" subscripts are used for a variety of variables. In the first subscript position subscripts symbols mean:

- p proposed - for the proposed building or design
- s standard - for the standard design

In the second subscript position subscript symbols are used:

- c calculation - for design calculation or sizing calculation
- s simulation - for the compliance simulation
- i input - for user input

In some instances, nom is added after the subscripts to indicate the nominal value of a variable requiring further adjustments.

For the sizing ratio, R, subscripts are used:

f = fans

c = cooling

h = heating

Calculate, R_f, the ratio of the actual proposed design fan air flow, cfm_{pi} and the calculated fan air flow requirement, cfm_{pc}, and determine the standard design fan sizing factor, F, and the proposed modeled supply air flow rate, cfm_{ps}, as follows:

if $R_f \geq 1.3$	$F = 1.3$	$cfm_{ps} = cfm_{pi}$
if $1.0 < R_f < 1.3$	$F = R_f$	$cfm_{ps} = cfm_{pi}$
if $R_f \leq 1.0$	$F = 1.0$	$cfm_{ps} = cfm_{pc}$

Adjust all zone supply air rates and supply air rates for groups of zones according to the procedure described above.

2. Calculate system coil loads by adjusting the proposed design calculated cooling loads for fan heat and ventilation loads.

3. Reheat coil sizes are as input by the user for interior zones. Reheat with series for perimeter zones are as input by the user but no smaller than 120% of the peak heating load assuming minimum supply air temperature. All VAV minimum positions are as input by the user but no smaller than the minimum ventilation quantity.

4. Calculate total individual cooling plant loads, $CCAP_{pc}$, as the sum of all calculated coil loads served by individual plants (e.g. direct expansion unit, chiller, etc.).

   Calculate, R_c, the ratio of the input proposed total plant cooling capacity, $CCAP_{pi}$, to the proposed calculated total cooling capacity, $CCAP_{pc}$, and determine the standard design cooling sizing factor, C, and the proposed nominal modeled total cooling capacity, $CCAP_{psnom}$, as follows:

if $R_c \geq 1.21$	$C = 1.21$	$CCAP_{psnom} = CCAP_{pi}$
if $1.0 < R_c < 1.21$	$C = R_c$	$CCAP_{psnom} = CCAP_{pi}$
if $R_c \leq 1.0$	$C = 1.0$	$CCAP_{psnom} = CCAP_{pc}$

$CCAP_{ps}$ is determined from $CCAP_{psnom}$ by adjusting for fan generated heat:

$$CCAP_{ps} = CCAP_{psnom} + 1.08(CFM_{ps} - CFM_{pc}) \times \text{Fan } T_p$$

5. Calculate individual heating plant loads, $HCAP_{pc}$, as the sum of all calculated coil loads served by individual plants (e.g. boiler, furnace, etc.).

   a) For system 1, the calculated proposed system heating capacity, $HCAP_{pc}$ is the larger of the actual fan cfm x 25 and the calculated steady state heating. Calculate, R_h, the ratio of the input proposed plant heating capacity, $HCAP_{pi}$, to the proposed calculated heating capacity, $HCAP_{pc}$, and determine the standard design heating sizing factor, H, and the proposed modeled heating capacity, $HCAP_{ps}$, as follows:

if $R_h \geq 1.43$	$H = 1.43$	$HCAP_{ps} = HCAP_{pi}$
if $1.2 < R_h < 1.43$	$H = R_h$	$HCAP_{ps} = HCAP_{pi}$
if $R_h \leq 1.2$	$H = 1.2$	$HCAP_{ps} = 1.2 \times HCAP_{pc}$

   b) For systems 3, 4 and 5, calculate, R_h, the ratio of the input proposed plant heating capacity, $HCAP_{pi}$, to the input calculated heating capacity, $HCAP_{pc}$, and determine the standard design heating sizing factor, H, and the proposed modeled heating capacity, $HCAP_{ps}$, as follows:

if $R_h \geq 1.43$	$H = 1.43$	$HCAP_{ps} = HCAP_{pi}$
if $1.2 < R_h < 1.43$	$H = R_h$	$HCAP_{ps} = HCAP_{pi}$
if $R_h \leq 1.2$	$H = 1.2$	$HCAP_{ps} = 1.2 \times HCAP_{pc}$

Modeling Rules for Standard Design (All):

1. Load calculations are performed for the standard building. Total system fan supply air flows are calculated using the same supply air temperatures used for the proposed design, except limited to the ranges listed in the standard design system inputs in Figures Table N2-11 through Table N2-14, and multiplied by the standard design sizing factor, F, determined in the proposed design sizing procedure.
2. Supply air quantities for each zone of multiple zone systems are determined by calculated zone loads, adjusted so that the block load adds up to the fan cfm.
3. Reheat coil sizes are determined with minimum VAV box positions of 0.8 for interior zones and 0.5 for perimeter zones on interior included reheat coils are only to the standard design if they have been input for the proposed design. Standard design VAV characteristics are determined as follows:

   Air flow rates for interior zones (only those without exterior walls) are further oversized by 33%. Minimum VAV settings for interior VAV zones are set to meet the larger of minimum ventilation requirements, 0.4 cfm/ft^2 or 30% of the zone peak supply air requirements. Reheat is added to meet ventilation loads only if input for the proposed design.

Minimum volume settings for exterior VAV zones are set to the larger of 0.4 cfm/ft^2 or 30% of the zone peak supply air requirements.

Standard system coil loads are calculated based on calculated zone loads adjusted for fan heat and ventilation loads, then adjusted again for piping loads (for hydronic systems only). Standard system plant capacities are determined by multiplying adjusted coil loads by the standard design sizing factors, C and H, determined in the proposed design sizing procedure.

Sizing Procedure for System 2

Modeling Rules for Proposed Design:

1. Calculate proposed fan air flow requirements, cfm_{pc}, based on the design supply air temperature input by the user or the default supply air temperature listed in the system description in Table N2-11. The calculated proposed fan air flow requirement is the larger of the heating and cooling air flow requirements, but no lower than 0.4 cfm/ft^2 overall.

   Calculate, R_f, the ratio of the actual proposed design fan air flow, cfm_{pi} and the calculated fan air flow requirement, cfm_{pc}, and determine the standard design fan sizing factor, F, and the proposed modeled supply air flow rate, cfm_{ps}, as follows:

if $R_f \geq 1.3$	$F = 1.3$	$Cfm_{ps} = cfm_{pi}$
if $1.0 < RF < 1.3$	$F = R_f$	$Cfm_{ps} = cfm_{pi}$
if $R_f \leq 1.0$	$F = 1.0$	$cfm_{ps} = cfm_{pc}$

   Adjust all zone supply air rates and supply air rates for groups of zones according to the procedure described above.

2. Calculate system coil loads by adjusting the proposed design calculated cooling loads for fan heat and ventilation loads.

3. Calculate, R_c, the ratio of the input proposed plant cooling capacity, $CCAP_{pi}$, to the same calculated capacity, $CCAP_{pc}$, and determine the standard design cooling sizing factor, C, and the proposed modeled cooling capacity, $CCAP_{ps}$, as follows:

if $R_c \geq 1.21$	$C = 1.21$	$CCAP_{ps} = CCAP_{pi}$
if $1.0 < R_c < 1.21$	$C = R_c$	$CCAP_{ps} = CCAP_{pi}$
if $R_c \leq 1.0$	$C = 1.0$	$CCAP_{ps} = CCAP_{pc}$

4. Calculate the amount of electric resistance heat, $HCAP_{pelec}$, by comparing the user input heating capacity at design conditions, $HCAP_{pdesign}$, to the actual heating load and using the following equations:

   $$HCAP_{pdesign} = HP \times HCAP_{pi}$$

   $$HLOAD_{pdesign} = HP \times HCAP_{sc}$$

   $$HCAP_{pelec} = 1.43 \times HLOAD_{pdesign} - HCAP_{pdesign}$$

5. If the user does not input design heat pump heating capacity, calculate HCAPelec according to the following procedure:

a) Calculate the heat pump design load factor, HP, from Equation N2-35.

b) Calculate $HCAP_{pdesign}$ by multiplying the rated heat pump heating capacity, input by the user, by HP.

c) Use the equation under step 4 to calculate $HCAP_{elec}$.

Modeling Rules for Standard Design (All):

1. Load calculations are performed for the standard building. Total system fan supply air flows are calculated using the standard design cooling load and the same supply air temperatures used for the proposed design, except limited to the ranges listed in the standard design system inputs in Table N2-11, and multiplied by the standard design fan sizing factor, F, determined in the proposed design sizing procedure.
2. Standard system coil loads are calculated based on calculated zone loads adjusted for fan heat and ventilation loads. Standard system cooling capacity is determined by multiplying adjusted coil loads by the standard design cooling sizing factors, C, determined in Step 3 of the proposed design sizing procedure, unless Step 4 below applies.
3. Standard design heating capacity, $HCAP_{ss}$, is determined from the following procedure:

a) $CCAP_{ss} = C \times (CCAP_{sc} + 1.08[CFMss\text{-}CFMsc] \times Fan\ T_s)$

and

$SCAP_{ss} = C \times SCAP_{sc}$

$HCAP_{ss} = CCAP_{ss}$

b) Calculate the heat pump design load factor, HP, from the following equation:

Equation N2-35 $$HP = 0.25367141 + 0.01043512\ K + 0.00018606\ K^2 - 0.00000149\ K^3$$

where

$K = T_{outside}$

c) Calculate the design heating capacity, $HCAP_{sdesign}$, by multiplying the rated heat pump heating capacity, input by the user, by HP.

$HCAP_{sdesign} = HP \times HCAP_{pi}$

$HLOAD_{sdesign} = HP \times HCAP_{sc}$

d) $HCAP_{sdesign}$ is adjusted to be the larger of $HCAP_{sdesign}$, and 75% of the actual design heating load adjusted for fan power and ventilation loads, $HLOAD_{sdesign}$, or

$HCAP_{sdesign} = \text{MAXIMUM}\ (HCAP_{sdesign}, 0.75 \times HLOAD_{sdesign})$

e) The electric heating capacity for the standard design is thus determined:

$HCAP_{selec} = 1.43 \times (HLOAD_{sdesign} - HCAP_{sdesign})$

f) If $HCAP_{sdesign}$ is determined from $0.75 \times HLOAD_{sdesign}$, then the modeled standard design heat pump heating capacity, $HCAP_{ss}$, is determined from the following equation:

$$HCAP_{SS} = HLOAD_{sdesign} / HP$$

$$CCAP_{SS} = HCAP_{SS}$$

2.5.3.9 Modeling Default Heating and Cooling Systems

Description: ACMs shall model the proper default heating and cooling systems when the user indicates, with the required ACM input, one of the following conditions for the building:

1. Mechanical compliance not performed. When the user indicates that no mechanical compliance will be performed, the ACM shall automatically model the default heating and cooling systems identical to the standard systems defined in Section 2.5.2.4 (Standard Design Systems). The ACM shall require the user to provide the information needed to determine the proper default system type.
2. Mechanical compliance performed with no heating installed. When the user indicates that mechanical compliance will be performed, but the entire project or portions of the space have no installed heating or are heated by an existing heating system, the ACM shall default to a heating system identical to the standard heating system defined in Section 2.5.2.4 (Standard Design Systems) for the space(s) with no installed heating or heated by an existing system. The ACM shall require the user to provide the information needed to determine the proper default system type.
3. Mechanical compliance performed with no cooling installed. When the user indicates with the required ACM input that mechanical compliance will be performed, but the entire project or portions of the space have no installed cooling or are cooled by an existing cooling system, the ACM shall default to a cooling system identical to the standard cooling system defined in Section 2.5.2.4 (Standard Design Systems) for the space(s) with no installed cooling or cooled by an existing system. The ACM shall require the user to provide the information needed to determine the proper default system type. The heating fuel source shall be fossil-fuel and the cooling source for residential and hotel/motel guest rooms shall be "other".

DOE-2 Keyword(s) SYSTEM-TYPE

Input Type Prescribed

Tradeoffs N/A

Modeling Rules for Proposed Design: The proposed design systems shall be determined as follows:

1. *Mechanical compliance not performed*. ACMs shall automatically size and model the default heating and cooling systems and adjust the heating by the standard design sizing factor of 1.2. ACMs shall select the proper mechanical system based on the building type and whether the permitted space is single zone (the conditioned floor area is less than 2500 ft^2) or multiple zone (the conditioned floor area is 2500 ft^2 or greater). See Section 4.3.3.1 (Thermal Zones) for guidelines for zoning a building. The heating fuel source shall be fossil-fuel and the cooling source for residential and hotel/motel guest rooms shall be "other".

   ACMs shall report the default heating and cooling energy use on PERF-1 and indicate that mechanical compliance was not performed. ACMs shall not print any Mechanical forms.

2. *Mechanical compliance performed with no heating installed*. ACMs shall

automatically size and model the default heating system for the entire project or portions of the space which have no installed heating or use an existing system and adjust the capacity by the standard design sizing factor of 1.2. ACMs shall select the type of heating system based on the building type and whether the permitted space is single zone or multiple zone. The heating fuel source shall be fossil fuel and the cooling source for residential and hotel/motel guest rooms shall be "other".

ACMs shall print all applicable mechanical forms and report the heating energy use for the entire project. ACMs shall report "No Heating Installed" for zones with no installed heating system and for zones using the existing heating system.

3. *Mechanical compliance performed with no cooling installed*. ACMs shall automatically size and model the default cooling system for the entire project or portions of the space which have no installed cooling or use an existing cooling system. ACMs shall select the type of heating system based on the building type and whether the permitted space is single zone or multiple zone. The heating fuel source shall be fossil fuel and the cooling source for residential and hotel/motel guest rooms shall be "other".

   ACMs shall print all applicable mechanical forms and report the cooling energy use for the entire project. ACMs shall report "No Cooling Installed" for zones with no installed cooling system and for zones using the existing cooling system.

   Proposed design supply air rates and heating capacity shall be determined according to procedures in Section 2.5.3.8 (Sizing Requirements) for the appropriate system type. Fan power shall be determined using 0.365 watts per cfm of supply air rate for the cooling system. The rate of supply air (in cfm) shall meet the building's minimum ventilation requirements.

   For occupancies other than the residential units of high-rise residential buildings and hotel/motel guest rooms, this default proposed cooling system shall also have an integrated dry-bulb economizer as specified in this section, regardless of the capacity.

Modeling Rules for Standard Design (All):

ACMs shall determine the standard design systems as follows:

1. *Mechanical compliance not performed*. ACMs shall automatically size and model the appropriate standard heating and cooling systems for the entire project using Section 2.5.2.4 (Standard Design Systems). ACMs shall use the standard design sizing factor of 1.2 for heating.
2. *Mechanical compliance performed with no heating installed*. ACMs shall automatically size and model the appropriate standard heating and cooling systems for the entire project using Section 2.5.2.4 (Standard Design Systems). ACMs shall adjust the heating capacity by the standard design sizing factor of 1.2.
3. *Mechanical compliance performed with no cooling installed*. ACMs shall automatically size and model the appropriate standard heating and cooling systems for the entire project using Section 2.5.2.4 (Standard Design Systems).

Standard design supply air rates, heating, and cooling capacity shall be determined according to procedures in Section 2.5.3.8 (Sizing Requirements) for the appropriate system type. Fan power shall be determined using 0.365 watts per cfm of supply air rate for the cooling system. The rate of supply air (in cfm) shall meet the building's minimum ventilation requirements.

For occupancies other than the residential units of high-rise residential buildings and hotel/motel guest rooms this default standard cooling system shall also have an integrated dry-bulb economizer as specified in this section, regardless of the HVAC system fan volume or cooling capacity.

2.5.3.10 System Supply Air Temperature Control

Description: ACMs shall be capable of modeling two control strategies, or reset strategies, for supply air temperature for any system compared to standard design systems 3 and 4. ACMs shall: (1) require the user to specify the control strategy used for controlling supply air temperature; and, (2) allow the user to enter the design cooling supply air temperature. Each of these strategies is described below.

Constant. Cooling supply air temperature is controlled to a fixed set point whenever cooling is required.

Outdoor Air Reset. Cooling supply air temperature resets upward during cool weather to reduce zone reheat losses. The ACM shall require the user to enter the reset schedule.

NOTE: Modeling dual duct systems in the proposed design requires the user to enter the heating supply air temperature control strategy as well. Refer to Chapter 3.

DOE-2 Keyword(s) HEAT-CONTROL
COOL-CONTROL
DAY-RESET-SCH

Input Type Default

Tradeoffs Neutral

Modeling Rules for Proposed Design: The reference method determines the supply air temperature control of the proposed design as input by the user according to the plans and specifications for the building. ACMs shall use the following schedule for the outdoor air reset:

SUPP-AIR-SCH	=	DAY-RESET-SCH
SUPPLY-HI	=	[SUPPLY-LO + 5]
SUPPLY-LO	=	[greater of SAT and 50]
OUTSIDE-HI	=	[SUPPLY-HI]
OUTSIDE-LO	=	[SUPPLY-LO].
SUPP-AIR-RESET	=	RESET-SCHEDULE THRU DEC 31,
(ALL)		SUPP-AIR-SCH

In the absence of the user input, ACMs shall use the Outdoor Air Reset control strategy for the proposed building.

Default: Outdoor Air Reset

Modeling Rules for Standard Design (All): The reference method shall use the same supply air temperature control strategy and schedule as the proposed design.

2.5.3.11 Zone Ventilation Air

Description: The reference method models mechanical supply of outdoor ventilation air as part of simulation of any fan system. The ventilation rate for a fan system is the sum of all ventilation requirements for all zones served by the same fan system.

ACMs shall allow the user to: 1) enter the ventilation rate for each zone; and, 2) identify the user input ventilation rate as a tailored ventilation rate. When tailored ventilation rates are entered for <u>any</u> zone, an ACM shall output on compliance forms that tailored ventilation rates have been used for compliance and that a Tailored Ventilation worksheet, and the reasons for different ventilation rates, shall be provided as part of the compliance documentation. Tailored ventilation inputs are designed to allow special HVAC applications to comply, but to be used they shall correspond to specific needs and the particular design and the plans and specifications used to meet those needs.

The reference method determines the minimum building ventilation rate by summing the ventilation rates for all zones determined from Table N2-2 or Table N2-3 as well as zones with justified tailored ventilation rates, input by the user.

DOE-2 Command

DOE-2 Keyword(s) OUTSIDE-AIR-CFM
MIN-OUTSIDE-AIR

Input Type Default

Tradeoffs N/A

Modeling Rules for Proposed Design: The reference method determines the proposed design zone ventilation rate as follows:

1. If no ventilation rate has been entered by the user, the ACM shall use values from Table N2-2 or Table N2-3 for the applicable occupancy as the zone ventilation rate for the proposed design.
2. If the zone ventilation rate has been entered by the user, the ACM shall use this value as the zone ventilation rate for the proposed design.

   This total shall not be less than the minimum ventilation rate calculated above. The ACM shall default to the minimum ventilation rate if the proposed ventilation rate, input by the user, is less than the minimum ventilation rate.
3. If the zone is controlled by DCV the ACM shall output on compliance forms that DEMAND CONTROL VENTILATION IS EMPLOYED FOR THIS ZONE PER SECTION 121 and shall use the larger of the following as the zone ventilation rate for the proposed design:
   a) half of the value from Table N2-2 or Table N2-3.
   b) The minimum rate.
   c) half of the user defined amount, if the zone ventilation rate has been entered by the user.

Default: Ventilation rates from Table N2-2 or Table N2-3.

Modeling Rules for Standard Design (All): The reference method determines the standard design zone ventilation rate as follows:

1. If no tailored ventilation rate has been entered, the ACM shall use values from Table N2-2 or Table N2-3for the applicable occupancy as the zone ventilation rate for the standard design.
2. If a tailored ventilation rate has been entered, the ACM shall assume the tailored value as the zone ventilation rate for the standard design.
3. If the zone is served by a single-zone system (in the proposed design) that has an air-side economizer and has a design occupant density greater than or equal to 25 people per 1000 ft^2 (40 ft^2 per person) from Table N2-2 or Table N2-3, unless space exhaust is greater than the design ventilation rate specified in 121 (b) 2 B minus 0.2 cfm per ft^2 of conditioned area, the ACM shall output on

compliance forms that DEMAND CONTROL VENTILATION IS REQUIRED FOR THIS ZONE PER SECTION 121 and the ACM shall use the larger of the following as the zone ventilation rate for the standard design:

a) half of the value from Table N2-2 or Table N2-3.

b) the minimum rate.

c) half of the user defined amount, if the zone ventilation rate has been entered by the user.

2.5.3.12 Zone Terminal Controls

Description:	ACMs shall be capable of modeling zone terminal controls with the following features: • *Variable air volume (VAV).* Zone loads are met by varying amount of supply air to the zone. • *Minimum box position.* The minimum supply air quantity of a VAV zone terminal control shall be set as a fixed amount per conditioned square foot or as a percent of peak supply air. • *(Re)heating Coil*. ACMs shall be capable of modeling heating coils (hot water or electric) in zone terminal units. ACMs may allow users to choose whether or not to model heating coils. • *Hydronic heating*. The ACM shall be able to model hydronic (hot water) zone heating. • *Electric Heating*. The ACM shall be able to model electric resistance zone heating. ACMs shall require the user to specify the above criteria for any zone terminal controls of the proposed system.
DOE-2 Keyword(s)	MIN-CFM-RATIO ZONE-HEAT-SOURCE
Input Type	Required
Tradeoffs	Yes
Modeling Rules for Proposed Design:	The reference method models any zone terminal controls for the proposed design as input by the user according to the plans and specifications for the building. All ACMs that explicitly model variable air volume systems shall not allow any minimum box position to be smaller than the air flow per square foot needed to meet the minimum occupancy ventilation rate.
Modeling Rules for Standard Design (New & Altered Existing):	For systems 3 and 4, the ACM shall model zone terminal controls for the standard design with the following features: Variable volume cooling and fixed volume heating Minimum box position set equal to the larger of: a) 30% of the peak supply volume for the zone; or b) The air flow needed to meet the minimum zone ventilation rate; or c) 0.4 cfm per square foot of conditioned floor area of the zone. Hydronic heating.

Modeling Rules for Standard Design (Existing Unchanged): The reference method models any zone terminal control for the existing design as it occurs in the existing system.

2.5.3.13 Pump Energy

Description: The reference method models energy use of pumping systems for hot water, chilled water and condenser water systems (cooling towers), accounting for energy use of pumps and additional cooling energy associated with pump energy rejected to the water stream.

DOE-2 Command

DOE-2 Keyword(s)
CCIRC-MOTOR-EFF
CCIRC-IMPELLER-EFF
CCIRC-HEAD
CCIRC-DESIGN-T-DROP
HCIRC-MOTOR-EFF
HCIRC-IMPELLER-EFF
HCIRC-HEAD
HCIRC-DESIGN-T-DROP
TWR-MOTOR-EFF
TWR-IMPELLER-EFF
TWR-PUMP-HEAD
TWR-RANGE

Input Type: Required

Tradeoffs: Yes

Modeling Rules for Proposed Design: The reference method calculates proposed design pump energy using the following inputs and procedures:

Hot Water Circulation Loop Pump

a) Impeller Efficiency = 67%

b) Motor Efficiency = Full-load efficiency of the electric motor established in accordance with NEMA Standard MG1 (see Section 2.5.2.15)

Equation N2-36

$$HCIRC-MOTOR-EFF = \frac{\sum_{i=1}^{n}(MEFF_{hwp\_i} \times HP_{hwp\_i})}{\sum_{i=1}^{n} HP_{hwp\_i}}$$

where

$MEFF_{hwp\_i}$ = Hot water pump motor efficiency

HP_{hwp_i} = Hot water pump motor nameplate HP

n = Number of hot water pump motors

c) Motor Horsepower — As designed

d) Flow Rate — As designed (in GPM)

e) Temperature Drop — Design boiler capacity (Btu)/(500×GPM) (in ^{o}F)

f) Design Head — As designed with a maximum of 100 feet of water.

g) Pump Control — As designed

h) Valve Types — Either 2-way or 3-way as designed

Chilled Water Circulation Loop Pump

a) Impeller Efficiency — 72%

b) Motor Efficiency — Full-load efficiency of the electric motor established in accordance with NEMA Standard MG1 (see Section 2.5.2.15)

Equation N2-37

$$CCIRC-MOTOR-EFF = \frac{\sum_{i=1}^{n}(MEFF_{chwp\_i} \times HP_{chwp\_i})}{\sum_{i=1}^{n} HP_{chwp\_i}}$$

where

$MEFF_{chwp\_i}$ = Chilled water pump motor efficiency

HP_{chwp_i} = Chilled water pump motor nameplate HP

n = Number of chilled water pump motors

c) Motor Horsepower — As designed

d) Flow Rate — As designed (in GPM)

e) Temperature Drop — Calculated as follows (in ^oF)

Equation N2-38

$$CCIRC-DESIGN-T-DROP = \frac{\sum_{i=1}^{n}(Q_{des\_i}) \times 12}{\sum_{i=1}^{n}(GPM_{evap\_i}) \times 0.5}$$

where

Q_{des_i} = Chiller design capacity in tons

GPM_{evap_i} = Flow rate in the evaporator in GPM

n = Number of chillers

f) Design Temperature — As designed (in ^oF)

g) Design Head — Minimum (100, $\Delta H_{chwsyspiping}$) in feet of water

Equation N2-39

$$\Delta H_{chwsyspiping} = \Delta H_{chwsys} - \frac{\sum_{i=1}^{n}(GPM_{evap\_i} \times \Delta H_{evap\_i})}{\sum_{i=1}^{n} GPM_{evap\_i}}$$

where

$\Delta H_{chwsyspiping}$	=	Chilled water piping system head
ΔH_{chwsys}	=	Chilled water system head
GPM_{evap_i}	=	Evaporator flow (in GPM)
ΔH_{evap_i}	=	Evaporator bundle pressure drop (in feet of water)
n	=	Number of evaporators in the system

h) Pump Control — As designed

i) Valve Types — Either 2-way or 3-way as designed

Condenser Water Circulation Loop Pump

a) Impeller Efficiency — 67%

b) Motor Efficiency — Full-load efficiency of the electric motor established in accordance with NEMA Standard MG1 (see Section 2.5.2.15)

Equation N2-40

$$TWR-MOTOR-EFF=\frac{\sum_{i=1}^{n}(MEFF_{cwp\_i}\times HP_{cwp\_i})}{\sum_{i=1}^{n}HP_{cwp\_i}}$$

where

$MEFF_{cwp\_i}$	=	Condenser water pump motor efficiency
HP_{cwp_i}	=	Condenser water pump motor nameplate HP
n	=	Number of condenser water pump motors

c) Motor Horsepower — As designed

d) Flow Rate — As designed (in GPM)

e) Range — As designed (in ^{o}F)

f) Design Head — Minimum (80, ΔH_{cws}) in feet of water

Equation N2-41

$$\Delta H_{cws}=\Delta H_{cwsys}+\frac{\sum_{i=1}^{n}(GPM_{evap\_i}\times\Delta H_{evap\_i})}{\sum_{i=1}^{m}GPM_{cond\_i}}$$

where

ΔH_{cwsys}	=	Condenser water system head
ΔH_{evap_i}	=	Evaporator bundle pressure drop (in feet of water)
ΔH_{cws}	=	Proposed condenser water system head
GPM_{evap_i}	=	Evaporator flow (in GPM)

GPM_{cond_i}	=	Condenser flow (in GPM)
n	=	Number of evaporators in the system
m	=	Number of condensers in the system

g) Cooling Tower Height — As designed

h) Pump Control — As designed

Modeling Rules for Standard Design (New):

The reference method calculates standard design pump energy using the following inputs and procedures:

Hot Water Circulation Loop Pump

a) Impeller Efficiency — 67%

b) Motor Efficiency — Standard motor efficiency from Table N2-17

c) Motor Horsepower — Same as the proposed design

d) Flow Rate (in GPM) — Calculated from standard boiler capacity

= Boiler Capacity / 15000

e) Temperature Drop — 30 ^{o}F

f) Standard Head — Same as proposed up to 100 feet of water

g) Pump Control — Fixed speed

h) Valve Types — 2-way

Chilled Water Circulation Loop Pump

a) Impeller Efficiency — 72%

b) Motor Efficiency — Standard motor efficiency from Table N2-17

c) Motor Horsepower — Same as the proposed design

d) Flow Rate (in GPM) — Calculated from standard chiller capacity

GPM = tons $\times$ 2.0

e) Temperature Drop — 12 ^{o}F

f) Design Temperature — 44 ^{o}F

g) Standard Head — Same as proposed design up to 100 feet of water

h) Pump Control — Variable speed

i) Valve Types — 2-way

Condenser Water Circulation Loop Pump

a) Impeller Efficiency — 67%

b) Motor Efficiency — Standard motor efficiency from Table N2-17

c) Motor Horsepower — Same as the proposed design

d) Range — 10 ^{o}F

e) Flow Rate (in GPM) — Calculated from standard chiller capacity

GPM = tons × (1 + 1/COP) × 2.4

f) Standard Head — Minimum (80, ΔH_{cws}) in feet of water

Equation N2-42

$$\Delta H_{cws} = \frac{\Delta H_{cwsyspiping}}{\text{Multiplier}} + 20 + \frac{\sum_{i=1}^{n}(GPM_{evap\_i} \times 20)}{\sum_{i=1}^{m} GPM_{cond\_i}}$$

where

Equation N2-43

$$\Delta H_{cwsyspiping} = \Delta H_{cwsys} - \frac{\sum_{i=1}^{m}(GPM_{cond\_i} \times \Delta H_{cond\_i})}{\sum_{i=1}^{m} GPM_{cond\_i}}$$

$\Delta H_{cwsyspiping}$ = Condenser water piping system head

ΔH_{cwsys} = Condenser water system head

ΔH_{cond_i} = Condenser bundle pressure drop (in feet of water)

ΔH_{cws} = Standard condenser water system head

GPM_{evap_i} = Evaporator flow (in GPM)

GPM_{cond_i} = Condenser flow (in GPM)

Multiplier = A multiplier from Table N2-18 for adjusting the condenser water piping system head based on pipe size and flow at connection to the cooling tower.

n = Number of evaporators in the system

m = Number of condensers in the system

g) Pump Control — Fixed speed

Default:

Hot water loop design head = 75 feet of water

Chilled water loop design head = 75 feet of water

Condenser water loop design head = 60 feet of water

Modeling Rules for Standard Design (Existing Unchanged & Altered Existing): ACM shall use the information from the existing pumping systems for the standard design. If this information is not available, ACMs shall use the above Standard Design values.

Table N2-18 – Pipe Head Multipliers Based on Pipe Size and Flow at Connection to the Cooling Tower

Proposed Flow		Normal Size		Undersize down to		Oversized up to	
From (GPM)	To (GPM)	Pipe Size (inch)	Multiplier	Pipe Size (inch)	Multiplier	Pipe Size (inch)	Multiplier
1	35	1.50	1.00	1.25	2.00	2.00	0.31
36	74	2.00	1.00	1.50	3.00	2.50	0.38
75	107	2.50	1.00	2.00	2.25	3.00	0.35
108	180	3.00	1.00	2.50	2.75	4.00	0.25
181	355	4.00	1.00	3.00	3.75	5.00	0.30
356	580	5.00	1.00	4.00	3.00	6.00	0.38
581	880	6.00	1.00	5.00	2.50	8.00	0.25
881	1,600	8.00	1.00	6.00	3.75	10.00	0.30
1,601	2,500	10.00	1.00	8.00	3.00	12.00	0.38
2,501	3,700	12.00	1.00	10.00	2.25	14.00	0.63
3,701	4,500	14.00	1.00	12.00	1.50	16.00	0.50
4,501	6,500	16.00	1.00	14.00	1.88	18.00	0.55
6,501	9,000	18.00	1.00	16.00	1.75	20.00	0.53
9,001	12,000	20.00	1.00	18.00	1.75	24.00	0.43
12,001	16,000	24.00	1.00	20.00	1.75	30.00	0.50
16,001	20,000	30.00	1.00	24.00	1.75	36.00	0.50
20,001	30,000	36.00	1.00	30.00	1.75	N/A	1.0
30,001	>30,001	Any Size	1.00	N/A	1.0	N/A	1.0

2.5.3.14 Chiller Characteristics

Description: The ACM chiller model shall, at a minimum, incorporate the following characteristics:

- *Minimum Ratio:* The minimum capacity for a chiller below which it cycles.
- *Electrical Input Ratio*: Efficiency of the chiller at rated conditions. It is the ratio of the electrical power input to the chiller to the nominal capacity of the chiller.
- *Condenser Type*: It specifies whether the condenser is air-cooled or water-cooled.
- *GPM per Ton*: The ratio of cooling tower water flow in GPM to chiller capacity in tons.

DOE-2 Keyword(s)
SIZE
MIN-RATIO
EIR
*-COND-TYPE
COMP-TO-TWR-WTR

Input Type: Required

Tradeoffs: Yes

Modeling Rules for Proposed Design: ACMs shall model chiller characteristics as follows:

SIZE: The chiller size shall be calculated as follows

Equation N2-44
$$SIZE = \frac{Q_{des\_i} \times 0.012}{CAPFT\left(t_{chws\_des}, t_{cws\_des}\right)}$$

where

Q_{des_i}	=	Chiller design capacity (in tons) at reference conditions
t_{chws_des}	=	Chilled water supply temperature at design conditions
t_{cws_des}	=	Condenser water supply temperature at design conditions
CAPFT()	=	Capacity performance curve (see 2.5.3.16)

Minimum Ratio: For chillers with customized curves, ACMs shall calculate the minimum ratio using the part-load data by

Equation N2-45
$$\text{MIN} - \text{RATIO} = \frac{Q_{des\_i}}{\text{Minimum}\left(\left[Q_{pload\_i1}, Q_{pload\_i2}, \ldots, Q_{pload\_ij}\right]\right)}$$

where

Q_{pload_ij}	=	Chiller part-load performance data, Capacity in tons
Q_{des_i}	=	Chiller design capacity (in tons)

The default minimum ratio values are shown in the table below.

Chiller Type	Default Unloading Ratio
Reciprocating	25%
Screw	15%
Centrifugal	10%
Scroll	25%
Single Effect Absorption	10%
Double Effect Absorption	10%

Electrical Input Ratio: ACMs shall calculate the Electrical Input Ratio (EIR) for chillers with customized performance curves from the user input data.

Equation N2-46
$$E-I-R = \frac{P_{des\_i} \times 3.413}{Q_{des\_i} \times EIRFT\left(t_{chws\_des}, t_{cws\_des}\right) \times EIRFPLR(1.0) \times 12.0}$$

$$\cancel{E - I - R = \frac{P_{des\_i} \times 3.413}{Q_{des\_i} \times 12.0}}$$

where

P_{des_i} = Chiller design input power at design conditions t_{chws_des} and t_{cws_des} (in kW)

Q_{des_i} = Chiller design capacity at design conditions t_{chws_des} and t_{cws_des} (in tons)

EIRFT()= Efficiency performance curve (see 2.5.2.6)

EIRFPLR()= Efficiency performance curve (see 2.5.3.16)

For other chillers, ACMs shall calculate the EIR using

Equation N2-47 $$E-I-R=\frac{1}{COP\times EIRFT(44,85)\times EIRFPLR(1.0)}$$

$$\cancel{E-I-R=\frac{1}{COP}}$$

where

COP	=	Coefficient of Performance
EIRFT()	=	Efficiency performance curve (see 2.5.3.16)
EIRFPLR()	=	Efficiency performance curve (see 2.5.3.16)

Condenser Type: ACMs shall require the user to input whether the chiller is air-cooled or water-cooled.

GPM per Ton: For water-cooled chillers with customized performance curves, ACMs shall determine the condenser water flow as a ratio of condenser water flow rate (GPM) to rated chiller capacity (tons) using the following equation.

Equation N2-48 $$COMP-TO-TWR-WTR=\frac{\sum_{i=1}^{n} GPM_{cond\_i}}{\sum_{i=1}^{m} Q_{des\_i}}$$

where

GPM_{cond_i}	=	Condenser flow rate (in GPM)
Q_{des_i}	=	Chiller design capacity (in tons)
n	=	Number of condensers
m	=	Number of chillers

For default water-cooled chillers, ACMs shall determine the condenser water flow as follows.

Equation N2-49 $$COMP-TO-TWR-WTR=\left[1+\frac{1}{\frac{\sum_{i=1}^{n}(COP_i\times SIZE_i)}{\sum_{i=1}^{n} SIZE_i}}\right]\times 2.4$$

where

COP_i = Coefficient of performance for chiller

Equation N2-50 $$SIZE_i = \frac{Q_{des\_i} \times 12{,}000}{1{,}000{,}000}$$

n = Number of chillers

Modeling Rules for Standard Design (New & Altered Existing):

ACMs shall model chiller characteristics for the standard design as follows:

SIZE: The chiller size shall be calculated as follows

Equation N2-51 $$SIZE = \frac{Q_i \times 0.012}{CAPFT(44{,}85)}$$

where

Q_i = Chiller capacity (in tons) at ARI reference conditions

CAPFT() = Capacity performance curve (see 2.5.3.16)

Minimum Ratio: ACMs shall calculate the minimum ratio default values are shown in the table below.

Chiller Type	Default Unloading Ratio
Reciprocating	25%
Screw	15%
Centrifugal	10%
Scroll	25%
Single Effect Absorption	10%
Double Effect Absorption	10%

Electrical Input Ratio: ACMs shall calculate the Electrical Input Ratio (EIR) for the standard design using

Equation N2-52 $$E-I-R = \frac{1}{COP \times EIRFT(44{,}85) \times EIRFPLR(1.0)}$$

where

COP = Coefficient of Performance

EIRFT() = Efficiency performance curve (see 2.5.2.33)

EIRFPLR() = Efficiency performance curve (see 2.5.3.16)

Condenser Type: ACMs shall model water-cooled condenser for the standard design.

*-COND-TYPE = TOWER

GPM per Ton: For water-cooled chillers with, ACMs shall determine the condenser water flow as follows.

Equation N2-53

$$COMP-TO-TWR-WTR = \left[1 + \frac{1}{\dfrac{\sum_{i=1}^{n}(COP_i \times SIZE_i)}{\sum_{i=1}^{n} SIZE_i}}\right] \times 2.4$$

where

COP_i = Coefficient of performance for chiller i

Equation N2-54

$$SIZE_i = \frac{Q_{des\_i} \times 12{,}000}{1{,}000{,}000}$$

n = Number of chillers

Modeling Rules for Standard Design (Existing Unchanged): ACMs shall model the existing chiller(s) using the actual data. If the actual data is not available, ACMs shall model the existing design the same as the standard design.

2.5.3.15 Number, Selection, and Staging of Chillers and Boilers

Description: The reference method accounts for staging of multiple cooling/heating units input for both the standard and proposed design.

DOE-2 Keyword(s): INSTALLED-NUMBER
TYPE

Input Type: Required

Tradeoffs: Yes

Modeling Rules for Proposed Design: ACMs shall model the number and staging of boilers and chillers as input and modeled by the user according to the plans and specifications for the building. All chiller plants over 300 tons shall limit the size of air-cooled chillers to 100 tons or less.

Modeling Rules for Standard Design (New): The reference method selects the standard design chiller types as follows:

- Total cooling plant load < 150 tons: the standard system uses one (1) water-cooled scroll chiller.
- 150 tons ≤ total cooling plant load < 300 tons: the standard system uses one (1) water-cooled screw chiller.
- 300 tons ≤ total cooling plant load ≤ 600 tons: the standard system uses two (2) equally sized water-cooled centrifugal chillers.
- Total cooling plant load > 600 tons: the standard system uses a minimum of

two (2) water-cooled centrifugal chillers but add machines as required to keep the maximum single unit size at or below 1000 tons.

ACMs shall bring up each chiller to 90 percent capacity prior to the staging of the next chiller. ACMs shall model the staged chillers in parallel.

The reference method selects the standard design boiler types as follows:

- Total heating plant load < 6,000,000 Btuh: the standard system uses one (1) atmospheric boiler (no combustion air fan).
- Total heating plant load $\geq$ 6,000,000 Btuh: the standard system uses two (2) atmospheric boilers (no combustion air fans) of equal size.

ACMs shall bring up each boiler to 90 percent capacity prior to the staging of the next boiler. ACMs shall model the staged boilers in parallel.

Modeling Rules for Standard Design (Existing Unchanged & Altered Existing): ACMs shall model the number and staging of boilers and chillers as input and modeled by the user according to the existing design of the central heating and cooling plants.

2.5.3.16 Performance Curves for Gas Absorption and Electric Chillers

Description The reference method models the performance curves of electric chillers as functions of variables such as the load, condenser water temperature, and flow rate.

The reference program uses a computer program to calculate custom regression constants for gas absorption and electric chillers. This program calculates the regression constants for performance curves according to the following rules, criteria, inputs, and outputs:

1. The curves are generated using ARI 550/590 or ARI 560 certified data.
2. The data have a minimum of 25 full-load points and 10 part-load points.
3. The full-load data represent a chilled water temperature range of (design-2) °F to (design+6) °F and a condenser water temperature range of 55°F to 85°F (or an outside dry-bulb temperature range of 45°F to 110°F for air-cooled equipment).
4. The part-load data represent unloading using both condenser relief and fixed design condenser temperature.
5. The rms error for power prediction on the data set is 5% or less.
6. The program report the APLV points as entered by the user and the chiller curve predicted performance at the same conditions.
7. The user cannot directly modify either the curve coefficients or the parameters including reference capacity, reference power, minimum unloading ratio, or maximum available capacity.

The program inputs are:

1. Make and model,
2. Chiller type,
3. Evaporator flow rate,
4. Evaporator bundle pressure drop,
5. Chiller design capacity,

6. Chiller design input power (gas and electric separately),
7. Chiller design chilled water supply temperature, and
8. Chiller design entering condenser water temperature (water-cooled), or
9. Chiller design outdoor dry-bulb temperature (air -cooled), and
10 Chiller APLV capacity,
11. Chiller APLV input power (gas and electric separately),
12. Chiller APLV chilled water supply temperature, and
13. Chiller APLV entering condenser water temperature (water-cooled), or
14. Chiller APLV outdoor dry-bulb temperature (air-cooled).

The program outputs are:

1. Predicted Coefficient Of Performance (COP) to within 5% of the manufacturer's data,
2. Four predicted APLV points with a maximum rms error of 5 percent of the manufacturer's data, and
3. Regression coefficients.

For all of the chiller curves, there is a rated condition at which the curves are unity. These are a rated capacity and efficiency at full load and specific chilled water and condenser water supply temperatures. The default curves in DOE2.1E are all rated at 44°F chilled water supply temperature and 85°F condenser water supply temperature. These are the ARI 550/590 rating conditions. For custom curves these references will be $CHWS_{des\_i}$ and CWS_{des_i} (or OAT_{des_i} for air-cooled equipment).

Three curves are used to determine the performance of each chiller:

EIR-FPLR	Percentage full-load power as a function of percentage full-load output.
CAP-FT	Capacity correction factor as a function of chilled water supply temperature and condenser water supply temperature.
EIR-FT	Efficiency correction factor as a function of chilled water supply temperature and condenser water supply temperature.

For air-cooled equipment the CAP-FT and EIR-FT curves are developed against the chilled water supply and outside air dry-bulb temperatures.

Each of the default curves are given in terms of regression constants (a through f). The regression equations have the following formats:

Equation N2-55

$$CAP\_FT = a + b \times CHWS + c \times CHWS^2 + d \times CWS + e \times CWS^2 + f \times CHWS \times CWS$$

$$EIR\_FT = a + b \times CHWS + c \times CHWS^2 + d \times CWS + e \times CWS^2 + f \times CHWS \times CWS$$

$$PLR = \frac{Q}{Q_{des} \times CAP\_FT(CHWS_{des}, CWS_{des})}$$

$$EIR\_FPLR = a + b \times PLR + c \times PLR^2$$

For Gas Absorption Chillers EIR curve fits are replaced by HIR curve fits.

$$HIR\_FT1 = a + b \times CHWX + c \times CHWX^2$$

$$HIR\_FT2 = a + b \times CWS + c \times CWS^2$$

$$HIR\_FPLR = a + b \times PLR + c \times PLR^2$$

$$EIR = QELEC / QCAPNOM$$

$$CAP\_FT(CHWX) = 1.00$$

where:

PLR	Part load ratio based on available capacity (not rated capacity)
Q	Present load on chiller (in tons)
Q_{des}	Chiller design capacity (in tons)
CHWS	Chiller chilled water supply temperature ^oF
CHWX	Leaving chilled water temperature ^oF
CWS	Entering condenser water temperature ^oF
$CHWS_{des}$	Chiller design chilled water supply temperature ^oF
CWS_{des}	Design entering condenser water temperature ^oF

For air-cooled equipment OAT is used in place of CWS in the CAP_FT and EIR_FT equations, where OAT is the outdoor dry-bulb temperature.

DOE-2 Command	
DOE-2 Keyword(s)	CURVE-FIT
Input Type	Default
Tradeoffs	Yes
Modeling Rules for Proposed Design:	The reference program uses a computer program with capabilities, calculation criteria, and input and output requirements as described above for producing regression constants for performance curves of electric chillers specified on the plans and specifications for the building.
Default:	Same regression constants and performance curves as those used for the standard design.
Modeling Rules for Standard Design (All):	ACMs shall use the regression constants in Table N2-19 through Table N2-24 for the performance curves of electric chillers.

Table N2-19 – Default Capacity Coefficients for Electric Air-Cooled Chillers

Coefficient	Scroll	Recip	Screw	Centrifugal
a	0.40070684	0.57617295	-0.09464899	N/A
b	0.01861548	0.02063133	0.03834070	N/A
c	0.00007199	0.00007769	-0.00009205	N/A
d	0.00177296	-0.00351183	0.00378007	N/A
e	-0.00002014	0.00000312	-0.00001375	N/A
f	-0.00008273	-0.00007865	-0.00015464	N/A

Table N 2-20 – Default Capacity Coefficients for Electric Water-Cooled Chillers

Coefficient	Scroll	Recip	Screw	Centrifugal
a	0.36131454	0.58531422	0.33269598	-0.29861976
b	0.01855477	0.01539593	0.00729116	0.02996076
c	0.00003011	0.00007296	-0.00049938	-0.00080125
d	0.00093592	-0.00212462	0.01598983	0.01736268
e	-0.00001518	-0.00000715	-0.00028254	-0.00032606
f	-0.00005481	-0.00004597	0.00052346	0.00063139

Table N2-21 – Default Efficiency EIR-FT Coefficients for Air-Cooled Chillers

Coefficient	Scroll	Reciprocating	Screw	Centrifugal
a	0.99006553	0.66534403	0.13545636	N/A
b	-0.00584144	-0.01383821	0.02292946	N/A
c	0.00016454	0.00014736	-0.00016107	N/A
d	-0.00661136	0.00712808	-0.00235396	N/A
e	0.00016808	0.00004571	0.00012991	N/A
f	-0.00022501	-0.00010326	-0.00018685	N/A

Table N2-22 – Default Efficiency EIR-FT Coefficients for Water-Cooled Chillers

Coefficient	Scroll	Reciprocating	Screw	Centrifugal
a	1.00121431	0.46140041	0.66625403	0.51777196
b	-0.01026981	-0.00882156	0.00068584	-0.00400363
c	0.00016703	0.00008223	0.00028498	0.00002028
d	-0.00128136	0.00926607	-0.00341677	0.00698793
e	0.00014613	0.00005722	0.00025484	0.00008290
f	-0.00021959	-0.00011594	-0.00048195	-0.00015467

Table N2-23 – Default Efficiency EIR-FPLR Coefficients for Air-Cooled Chillers

Coefficient	Scroll	Recip	Screw	Centrifugal
a	0.06369119	0.11443742	0.03648722	N/A
b	0.58488832	0.54593340	0.73474298	N/A
c	0.35280274	0.34229861	0.21994748	N/A

Table N2-24 – Default Efficiency EIR-FPLR Coefficients for Water-Cooled Chillers

Coefficient	Scroll	Recip	Screw	Centrifugal
a	0.04411957	0.08144133	0.33018833	0.17149273
b	0.64036703	0.41927141	0.23554291	0.58820208
c	0.31955532	0.49939604	0.46070828	0.23737257

2.5.3.17 Cooling Towers

Description: The ACM cooling tower model shall, at a minimum, incorporate the following characteristics:

- *Open circuit*: Condenser water is cooled by evaporation by direct contact with ambient outdoor air stream.
- *Centrifugal or propeller fan*: A centrifugal or propeller fan provides ambient air flow across evaporative cooling media.
- *Staging of Tower Cells*: Capacity is varied by staging of tower cells.
- *Electrical input ratio*: The ratio of peak fan power to peak heat rejection capacity at rating conditions.

DOE-2 Keyword(s)
TYPE
INSTALLED-NUMBER
TWR-CELL-CTRL
TWR-CELL-MIN-GPM
MIN-RATIO
EIR
TWR-DESIGN-WETBULB
TWR-DESIGN-APPROACH
TWR-SETPT-T
TWR-CAP-CTRL

Input Type: Required

Tradeoffs: Yes

Modeling Rules for Proposed Design: ACMs shall model cooling towers as follows:

Sizing. ACMs shall autosize the cooling tower using the following parameters:

1. 0.5% Cooling Design Wet-Bulb Temperature in Joint Appendix II.
2. Design Approach Temperature as input by the user according to the plans and specifications for the building.
3. Number of Tower Cells as input by the user according to the plans and specifications for the building.

If the number of cells is specified, then

INSTALLED-NUMBER = # of cells input by the user

If the number of cells is not specified, then

Equation N2-56

$$\text{INSTALLED}-\text{NUMBER} = \frac{\sum_{i=1}^{n} Q_{des\_i}}{1000}$$

where:

Q_{des_i} = Chiller design capacity (in tons)

n = Number of chillers

Staging of Tower Cells. The user shall specify whether the tower is controlled with the minimum or maximum number of cells possible a to keep the flow rate per cell within the allowable minimum and maximum flow ranges.

Fan Control. ACMs shall accept input by the user for the cooling tower fan control according to the plans and specifications for the building.

Condenser Water Set-point Control. ACMs shall use a set-point temperature of 70 ^{o}F.

Electrical Input Ratio. ACMs shall calculate the Electrical Input Ratio (EIR) as follows:

Equation N2-57

$$E-I-R = \frac{HP_{CT} \times 2.545}{\sum_{i=1}^{n} (Q_{des\_i} \times 12 + P_{des\_i} \times 3.413)}$$

where:

HP_{CT} = Cooling tower nameplate horsepower per cell

Q_{des_i} = Chiller design capacity (in tons)

P_{des_i} = Chiller design input power (in kW)

n = Number of chillers

Modeling Rules for Standard Design (New):

The reference method uses a single cooling tower with the following features for the standard design system:

Sizing. ACMs shall autosize the cooling tower using the following parameters:

1. Design Wet-Bulb Temperature using 0.5% design wet-bulb column of ASHRAE publication SPCDX: Climatic Data for Region X, Arizona, California, Hawaii, and Nevada, 1982.
2. Design Approach Temperature of 10^{o}F.
3. Number of Tower Cells equal to the proposed design. If the proposed design uses air-cooled chillers (no cooling towers), the number of Tower Cells shall be equal to the number of chillers in the standard design.

Staging of Tower Cells. The standard design shall use a control scheme to use the maximum number of cells possible and stage on as many cells as can be staged to keep the flow rate per cell above 50 percent of maximum.

TWR-CELL-CTRL = MAX-CELLS

Fan Control. The standard design shall use a two-speed fan control system.

TWR-CAP-CTRL = TWO-SPEED-FAN

Fan Speed. The standard design shall use the following setting for minimum fan speed.

TWR-CELL-MIN-GPM = 0.33

Condenser Water Set-point Control. The standard design shall use the same set-point temperature as the proposed design.

Electrical Input Ratio. The standard design shall use an EIR of 0.0133.

Modeling Rules for Standard Design (Existing Unchanged & Altered Existing):

ACMs shall model the existing cooling tower(s) using the actual data. If the actual data is not available, ACMs shall model the existing design the same as the standard design.

2.5.3.18 HVAC Distribution Efficiency of Packaged Equipment

Scope	These modeling rules apply for packaged equipment with ducts in unconditioned buffer spaces or outdoors as specified in Section 144(k) of the Standards.
Description:	ACMs shall be able to determine the efficiency of ducts in unconditioned buffer spaces or outdoors. ACMs shall require the user to enter the duct insulation R-value, the number of building stories, and whether or not the ducts will be sealed and tested for reduced duct leakage.
DOE-2 Command	
DOE-2 Keyword(s)	None. Duct efficiency divisors for COOLING-EIR, COOLING-EIR-SEER and HEATING-HIR will be calculated by means of the equations in Appendix ACM NG.
Input Type	Default
Tradeoffs	Yes
Modeling Rules for Proposed Design:	The ACM shall calculate the duct efficiency for the Proposed Design as specified in Appendix ACM NG based on the user inputs specified in this section. The ACM shall require the user to input duct R-value, the number of building stories, the presence of a cool roof, and whether or not credit for reduced duct leakage will be claimed and tested.
Default:	Duct R-value of 8.0 [h^{o}F ft^{2}/Btu] and duct leakage of 8% of fan flow. Number of stories is defaulted to one (1).
Duct Sealing Caution	Warning on PERF-1 if improved HVAC distribution efficiency through duct sealing is claimed. Warning shall include minimum qualification criteria described in Appendix ACM NG, Section NG.4.3.8.
Modeling Rules for Standard Design (New):	The ACM shall use the duct leakage factors for duct systems in newly constructed buildings from Table NG-2 of Appendix ACM NG for the Standard Design.
Modeling Rules for Standard Design (Existing Unchanged & Altered Existing):	See Section 3.1.3 on duct sealing in alterations and additions.

2.5.3.19 HVAC Transport Efficiency

Description:	ACMs shall report the ratio between the energy expended to transport heating, cooling and ventilation throughout the building, and the total thermal energy delivered to the various zones in the building.
Modeling Rules:	The transport energy includes all distribution-fan, ventilation-fan and non-DHW pump consumption, and the thermal energy delivered is the sum of all zone loads. This ratio shall be calculated both over the course of the year, and under design conditions.

TE = (distribution fan energy + ventilation fan energy + non-DHW pump energy)/(total thermal load)

2.6 Service Water Heating

ACMs shall be capable of modeling service water heating systems for nonresidential and high-rise residential buildings. The service water heating system shall be modeled whether or not it is part of combined hydronic system that serves both space and service water heating demands. ACMs are required to model independent systems for service water heating. ACMs shall require the user to identify if service water heating is included in the performance compliance submittal. ACMs shall also require the user to identify the type of service water heating systems as described below and in Appendix RG of the residential ACM manual.

2.6.1 Nonresidential Service Water Heating (Including Hotels Guest Rooms)

ACMs shall be able to accept inputs to distinguish electric or gas water heating systems and shall either assume part-load performance curves for the types of water heaters allowed to be entered OR allow entry of an efficiency (some sort of annual or seasonal efficiency is preferred but a steady state efficiency is acceptable) for the water heating system. The ACM shall be able to accept inputs from the user for a recirculating water heating system or an electrically traced (electric tape) water heating system.

The standard water heating system for either of these two systems is a water heating system with all hot water pipes insulated and a gas boiler with an efficiency as required by the Appliance Efficiency Standards or Table 112-F of the Standards. For hotels and high-rise residential buildings, the standard water heating system is a recirculating system.

Water heating shall be modeled using the hourly loads for each occupancy as shown in Table N2-2 or Table N2-3, multiplied by the fraction of load in each hour shown in the water heating schedule in the standard schedules These loads shall be combined for each zone to develop a total building water heating load for each hour. Each water heater shall be assigned an individual load, and shall be modeled independent of other water heaters.

2.6.1.1 Algorithms and Assumptions

For nonresidential buildings, the hourly water heating energy use shall be determined from Equation N2-58.

Equation N2-58 $$WHEU_n = SRL \times F_{whpl(n)} \times DHWHIR \times HIRCOR$$

where

$WHEU_n$ = Water heating energy use for the n^{th} hour

$F_{whpl(n)}$ = Hourly load multiplier for the n^{th} hour from Table N2-4 through Table N2-8

SRL = Standard Recovery Load in Btu/hr, derived from the loads per person shown in Table N2-1 or N2-2 for the occupancy served by the water heater. If a water heater may serve more than one occupancy, the load should be weighted by the number of square feet in each occupancy served by the water heater.

DHWHIR = Heating input ratio of the water heater(s) which is equal to the inverse of the recovery efficiency (RE) or thermal efficiency (TE). The recovery efficiency for electric water heaters is 0.98.

HIRCOR = Part-load correction factor

HIRCOR is determined from the following procedure, given in the form of a DOE 2.1 curve fit instruction:

DHW-HIR-FPLR = ACM-DHW-CRV

ACM-DHW-CRV = CURVE-FIT

TYPE = LINEAR

COEFFICIENTS = (DHW-A,DHW-B)

These commands yield an equation for HIRCOR of:

$$HIRCOR = (DHW\text{-}A) + (DHW\text{-}B) \times PLR$$

Where:

Equation N2-59 $$DHW - A = \frac{STBY}{INPUT}$$

Equation N2-60 $$DHW - B = \frac{(INPUT \times RE^*) - STBY}{SRL}$$

* or Thermal Efficiency (*TE*)

PLR_n = Part-load ratio for the n^{th} hour and shall always be less than 1. PLR_n is calculated from the following equation:

Equation N2-61 $$PLR_n = \frac{SRL \times F_{whpl(n)}}{INPUT \times RE^*}$$

* or Thermal Efficiency (*TE*)

INPUT = The input capacity of the water heater expressed in Btu/hr.

STBY = Hourly standby loss expressed in Btu/hr.

For storage type water heaters, not in the scope of Covered Consumer Products as defined in the Title 10 or the Code of Federal Regulations, Part 430;

Equation N2-62 $$STBY = 453.75 \times S \times VOL$$

where

S = The standby loss fraction listed in the Commission's Appliance Database of Certified Water Heaters,

VOL = The actual storage capacity of the water heater as listed in the Commission's Appliance Database of Certified Water Heaters,

For storage type water heaters that are NAECA covered products, the standby loss shall be calculated with the following equation.

Equation N2-63 $$STBY = \frac{1440.104 \times \left(\frac{1}{EF} - \frac{1}{RE^*}\right)}{\left(1 - \frac{1701.941}{(INPUT \times RE^*)}\right)}$$

* or Thermal Efficiency (*TE*)

where:

EF = Energy Factor

For instantaneous water heaters that are not Covered Consumer Products,

STBY = PILOT

Where PILOT is the pilot light energy use in Btu/hr

Required inputs and standard and proposed design assumptions depend on the type of water heater and whether or not it is a DOE covered consumer product.

2.6.1.2 DOE Covered Water Heaters

Description:	ACMs shall require the user to enter fuel type (electricity or gas), input, volume, energy factor, recovery efficiency or thermal efficiency, and quantity for DOE covered storage-type water heaters.
DOE-2 Keyword(s)	DHW-TYPE DHW-SIZE DHW-EIR DHW-EIR-FT DHW-EIR-FPLR
Input Type	Required
Tradeoffs	Neutral
Modeling Rules for Proposed Design:	The proposed design shall assume fuel type, input, volume, energy factor, recovery efficiency or thermal efficiency, and quantity as input by the user and as shown in the construction document for the building.
Modeling Rules for Standard Design (All):	The standard design shall assume fuel type, input, volume, recovery efficiency or thermal efficiency, and quantity identical to the proposed design. The standard design shall assume an energy factor, calculated as a function of the volume, according to equations found in the Appliance Efficiency Regulations.

2.6.1.3 Water Heaters not Covered by DOE Appliance Standards

Description:	ACMs shall require the user to enter fuel type, input, volume, recovery efficiency or thermal efficiency, standby loss and quantity for all storage type water heaters that are not covered by DOE appliance standards.
DOE-2 Command	
DOE-2 Keyword(s)	DHW-TYPE DHW-SIZE DHW-HEAT-RATE DHW-EIR DHW-EIR-FT DHW-EIR-FPLR DHW-LOSS
Input Type	Required
Tradeoffs	Neutral
Modeling Rules for Proposed Design:	The proposed design shall assume fuel type, input, volume, recovery efficiency or thermal efficiency, standby loss and quantity as input by the user and as shown on the construction documents for the building.
Modeling Rules for Standard Design (All):	The standard design shall assume fuel type, input, volume and quantity that are identical to the proposed design. The standard design shall assume recovery efficiency or thermal efficiency and standby loss as specified in either Section 111 or 113 of the Building Energy Efficiency Standards.

2.6.1.4 Boilers

If a boiler (or boilers) serve both space and service water heating systems, the ACM shall assign space heating and recovery loads to the boiler for both the standard and proposed designs. Boilers shall be simulated as described in Section 2.5.2.12.

2.6.1.5 Unfired Indirect Water Heaters (Storage Tanks)

ACMs shall simulate jacket losses and effective recovery efficiency for unfired indirect water heaters and storage tanks. Jacket losses shall be calculated using the following equation:

Equation N2-64
$$JL = \frac{117.534VOL^{0.66} + 99.605VOL^{0.33} + 21.103}{REI} + 61.4$$

where:

JL = Hourly jacket loss in Btu

VOL = Volume of indirect heater or storage tank in gallons

REI = R-value of exterior insulating wrap

The adjusted hourly recovery load seen by the primary water heating devices described above (e.g. water heater or boiler) shall be calculated according to Equation N2-65

Equation N2-65
$$PARL_n = \frac{SRL \times F_{whpl(n)} \times JL}{0.98}$$

Where:

$PARL_n$ = Adjusted recovery load seen by the primary water heating device for the n^{th} hour

DOE-2 Command	
DOE-2 Keyword(s)	DHW-LOSS
Input Type	Required
Tradeoffs	Neutral
Modeling Rules for Proposed Design:	ACMs shall assume indirect water heaters with volume and REI as input by the user and as shown in the construction documents for the building. ACMs shall not allow the user to enter an REI of less than 12.
Modeling Rules for Standard Design (All):	If an indirect water heater is input as part of the proposed design, that standard design shall assume an indirect heater with the same volume as the proposed design and REI of 12.

2.6.2 High-Rise Residential Water Heating Calculation Methods

For high-rise residential buildings, ACMs shall calculate the energy consumption of the proposed water heating system(s) and the water heating energy budget in accordance with procedures in the Residential ACM Manual, and Residential ACM Appendix RG. Alternatively, users may show service water heating compliance using the prescriptive requirements of Section 151(f)(8) of the Standards. In this case, water heating is left out of the performance calculations.